THE SEMICONDUCTOR DATA LIBRARY

MOTOROLA Semiconductor Products Inc.

FIRST EDITION   VOLUME I

TYPE NUMBERS UP TO 1N4999, 2N4999

THE SEMICONDUCTOR DATA LIBRARY

FIRST EDITION

prepared by
Technical Information Center

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Die in diesem Buch enthaltenen Angaben wurden sorgfältig überprüft und sind nach unserer Meinung völlig zuverlässig. Wir können jedoch für die Genauigkeit dieser Angaben keine Verantwortung übernehmen. Darüber hinaus wird dem Käufer von Halbleiterelementen mit Angaben, die in dieser Bibliothek genannt werden, keine unter die Patentrechte eines Herstellers fallende Lizenz erteilt.

First Edition
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THE SEMICONDUCTOR DATA LIBRARY

One of the major problems facing workers in the electronics field is the identification and selection of semiconductor devices. Type numbers assigned to the semiconductors are of little value since they indicate neither device parameters nor applications. Because it is difficult even to identify the many thousands of device type numbers, let alone evaluate their merits for a particular application, engineers often limit their designs to a few well-known device types – despite the fact that newer or more suitable devices may be available. To help alleviate this problem, the Motorola Semiconductor Data Library has been developed.

The Motorola Semiconductor Data Library identifies and characterizes all semiconductor devices with 1N- - -, 2N- - -, and 3N- - - numbers registered with the Electronics Industries Association at the time the library was printed, as well as a broad line of devices with special in-house type numbers. (It provides complete data sheet specifications for a wide range of discrete semiconductors, and short-form specifications for integrated circuits.) And in addition, to simplify the selection of the most useful semiconductor type numbers, it contains carefully prepared selector guides with recommended devices for specific applications. Properly used, it can be a valuable aid for the design engineer, the component engineer, and the purchasing agent in narrowing the broad categories of potentially usable components to those best suited for a specific project.

COMPOSITION OF THE LIBRARY

The Semiconductor Data Library is divided into three volumes, organized as follows:

REFERENCE VOLUME

The reference volume is a self-contained compendium of semiconductor devices and integrated circuits information. This volume enables the user to locate and select devices for most any application or specific circuit. It also contains package and hardware information as well as applications information. Once a preliminary selection of a potentially suitable device has been made, consult Volumes I or II for detailed specifications for that particular device.

EIA Registered Device Index – Complete numerical index of all EIA registered device types, with major electrical specifications.

Non-Registered Device Index – Complete numerical index of all in-house non-registered Motorola device types, with major electrical specifications.

Microcircuits Components – Unencapsulated transistors, diodes, passive devices, and integrated circuits for use in hybrid circuits. (Includes processing, packaging, and inspection criteria.)

Master Selection Guides – Grouping of preferred devices by major device categories for quick preselection of devices best suited for specific applications. Includes semiconductor devices and ICs.

Military Device Listing – A complete list of Motorola devices that comply with Military Specifications.

Hardware and Packaging Information – Device mounting hardware, heat sinks and special device packaging.

Dimensioned Device Outlines – Dimensioned drawings of package outlines with JEDEC and Motorola cross reference. (Includes leadform drawings on specific packages.)

Application Note Catalog – Selection guide listing application note by application category. Also a brief summary of the available application note contents and how to order application notes.

To meet the requirements of a practical up-to-date reference, the Reference Volume of the Semiconductor Library will be completely updated and published twice a year, with supplementary publications quarterly.

VOLUME I

This volume contains complete data sheets for Motorola-manufactured devices with EIA-registered type numbers up to 1N4999 and 2N4999. Data sheets are in numerical sequence according to device type number except for those data sheets that cover several devices with differing type numbers. A numerical index in front of the book permits the user to quickly locate the page number of the data sheet for any device characterized in the book.

Since most of the device type numbers in the "below 5000" category have already been utilized by existing product, it is expected that this book will require little updating in the next few years. Accordingly, this volume will be reprinted only as required by the demand, and modifications will be made only when reprinting is required.

VOLUME II

This volume contains data sheets for all Motorola-manufactured, EIA registered devices with type numbers 1N5000 and 2N5000 and up, as well as those with 3N- - - type numbers. In addition, all active data sheets for devices with special Motorola type numbers (not registered with EIA) are included.

Because this book contains the detailed data for all the most recently developed semiconductors, it will be updated through the publication of supplements. Two supplements will be published during the life of this edition.

How to Use The Semiconductor Data Library

The library is designed to serve several specific functions;

1. To permit quick identification (together with major specifications) of EIA registered semiconductor devices with units with special Motorola type numbers.
2. To permit quick selection of the most suitable devices for a specific circuit application.
3. To permit quick selection of the devices that best meet a given set of electrical specifications.
4. To provide complete characterization of a broad line of components, encompassing most semiconductor categories, for a detailed comparison of device types.

The following examples illustrate several ways of using this library.

Problem: Device Identification
Known: Device Type Number
Information Needed: Device function, applications, major specifications.

Procedure: Consult the Master Index of the Reference Volume and locate the type number of the device in question in the alpha-numeric listing of the master index. The information given in this index lists not only the type of device it is, but also provides the major electrical specifications for the device. In addition, it indicates whether or not the device is manufactured by Motorola and, if not, whether Motorola can supply an electrically suitable equivalent. Complete data for Motorola manufactured devices can then be obtained, if required, from the other two volumes of your Semiconductor Data Library.

Problem: Device Preselection
Known: a) Intended circuit application for a particular device
b) Approximate electrical specifications of a desired device.
Information Needed: a) What devices are available for a specific circuit function?
b) What device types will best match a required set of electrical characteristics?

Procedure: Consult the Master Selection Guide section of the Reference Volume. This section contains product categories, i.e., power transistors, zener diodes, etc., and by specific market segments, including communications, consumer and military. An index to the individual selector guides is given at the beginning of the section for quick access to the pertinent guides. Complete data for Motorola manufactured devices can then be obtained, if required, from the other two volumes of your Semiconductor Data Library.

CATALOGUE DE SEMICONDUCTEURS

Identifier et ensuite choisir les dispositifs semiconducteurs constituent l'un des grands problèmes que rencontrent ceux qui travaillent dans le domaine de l'électronique. Les différents dispositifs sont désignés par des chiffres ne donnant aucune indication sur leurs paramètres et sur leurs applications. La difficulté pour les techniciens et ingénieurs d'identifier plusieurs milliers de dispositifs les amènent à utiliser, lors de la conception de circuits, des dispositifs bien connus alors que d'autres dispositifs mieux adaptés sont disponibles. Afin de pallier cet inconvénient, Motorola a donc institué ce catalogue de semiconducteurs.

Le Catalogue de Semiconducteurs de Motorola identifie et caractérise les dispositifs semiconducteurs enregistrés auprès de l'Association des Industries Electroniques (EIA) par les symboles 1N---, 2N---, et 3N--- ainsi que les dispositifs propres à Motorola avec des numéros spéciaux. (Ce catalogue contient les spécifications complètes pour tous les semiconducteurs discrets, et des spécifications abrégées pour les circuits intégrés.) De plus, afin de simplifier le choix des dispositifs les plus utiles, il contient également un "guide" mettant en évidence les dispositifs destinés à des applications bien spécifiques. Son utilisation adéquate peut donc être un outil de travail très utile pour l'ingénieur de circuit, l'ingénieur de composants, et l'acheteur en leur permettant de limiter le nombre de composants possible convenent le mieux pour un projet bien determiné.

INDEX DU CATALOGUE

Le Catalogue de Semiconducteurs comprend trois volumes:

VOLUME DE REFERENCE

Le volume de référence résume les renseignements sur les dispositifs semiconducteurs et circuits intégrés. Ce volume permet donc à l'utilisateur de déterminer et de choisir les dispositifs pour la majorité des applications; il contient également des renseignements sur les boitiers et sur les systèmes de montage. Une fois le choix du dispositif effectué, il suffit de consulter les Volumes I et II pour obtenir toutes les données concernant ce dispositif.

Index des Dispositifs Homologués par EIA

Cet index fournit également les données électriques principales.

Index des Dispositifs Non-Homologués

Cet index fournit une liste complète des dispositifs Motorola non-homologués, avec leurs données électriques principales.

Composants Micro-circuits

Transistors et diodes non-encapsulés, éléments passifs et circuits intégrés pour utilisation en circuits hy-

brides (y compris processus, mise en boitier et critères d'inspection.)

Guide

Les dispositifs les plus utilisés y sont groupés par catégories principales, pour un choix rapide des composants les mieux adaptés à certaines applications (y compris dispositifs discrets et circuits intégrés.)

Liste des Dispositifs Militaires

Cette liste fournit tous les dispositifs Motorola homologués par les Spécifications Militaires.

Boitiers et Modes de Montage

Fournit les modes de montage, les radiateurs et les boitiers spéciaux.

Dimension des Boitiers

Dessin et dimension des boitiers homologués par JEDEC et Motorola (y compris les dessins pour former les tiges.)

Catalogue de Notes d'Applications

Fournit une liste complète des notes d'applications groupées par catégories, également un résumé des notes d'applications disponibles et la marche à suivre pour les obtenir.

Il est évident qu'afin de garder ce catalogue à jour, le Volume de Référence sera complètement révisé et publié deux fois par an, avec des additions supplémentaires publiées tous les trimestres.

VOLUME I

Ce volume est constitué par les specifications pour les composants faits par Motorola avec les numéros homologués par EIA jusqu'à 1N4999 et 2N4999. Ces spécifications sont classées par ordre numérique sauf les spécifications qui se rapportent à plusieurs types de dispositifs. Un index numérique en première page permet à l'utilisateur de déterminer rapidemente le numéro de la page pour chaque dispositif décrit dans ce catalogue.

Il est probable que les dispositifs portant un numéro en-dessous de 5000 nécessiteront peu de mise à jour puisque tous ces numéros sont déjà utilisés. En conséquence, ce volume ne sera réimprimé que sur demande et les modifications apparaîtront uniquement lors de cette nouvelle édition.

VOLUME II

Ce volume est constitué par toutes les spécifications pour les dispositifs faits par Motorola, homologués par EIA avec numéros 1N5000, 2N5000, etc. ainsi que ceux avec les numéros 3N---. De plus, les spécifications de dispositifs avec numéros spéciaux de Motorola (non homologués par EIA) y sont incluses.

Ce catalogue sera mis à jour à l'aide d'éditions supplémentaires, car il contient toutes les données détaillées des dispositifs semiconducteurs les plus récents. Deux suppléments seront publiés pendant la durée de vie de cette édition.

Méthode d'Utilisation du Catalogue de Semiconducteurs

Ce catalogue a pour but:

1. D'identifier rapidement, grâce aux spécifications principales, si le dispositif est homologué par EIA ou s'il s'agit d'un type spécial Motorola.
2. De sélectionner rapidement le dispositif le mieux adapté à un circuit.
3. De sélectionner rapidement un dispositif en fonction des spécifications électriques.
4. De fournir les données complètes de tout l'ensemble des composants Motorola — donc la majorité des dispositifs semiconducteurs — afin de pouvoir comparer tous les types de dispositifs.

Exemples de méthodes d'utilisation;

Question: Identifier le dispositif
Donnée: Type de dispositif
Renseignements Requis: Fonction du dispositif, applications et spécifications principales.

Méthode: Consulter l'Index du Volume de Référence et déterminer le numéro du dispositif en question parmi la liste numérique de l'index. Ce renseignement ainsi obtenu indique non seulement le type de dispositif mais également fournit les spécifications électriques principales de ce dispositif. De plus, le fabricant y sera précisé et le catalogue indiquera si Motorola peut fournir les dispositifs équivalents. Les deux autres volumes de ce catalogue vont maintenant fournir toutes les données sur les dispositifs faits par Motorola.

Question: Choix du Dispositif

Données:

a) Application probable du circuit pour un dispositif connu.

b) Spécifications électriques approximatives du dispositif en question.

Renseignements Requis:

a) Quels sont les dispositifs disponibles pour la fonction précise de ce circuit?
b) Quel type de dispositif va répondre à des caractéristiques électriques prédéterminées?

Méthode: Consulter le Guide dans le Volume de Référence qui est catégorisé par produits, c'est-à-dire transistors de puissance, diodes zener, etc., et par marchés, y compris communications, grand public, et militaire. Ces différentes catégories apparaissent en première page pour faciliter la sélection du Guide. Nous pouvons maintenant obtenir toutes les données sur les dispositifs faits par Motorola en utilisant les deux autres volumes du Catalogue de Semiconducteurs.

DIE HALBLEITER DATENBIBLIOTHEK

Eines der Hauptprobleme für Fachleute in der Elektronik-Industrie besteht in der Bestimmung und Selektion von Halbleitertypen. Die meisten Typenbezeichnungen geben wenig oder keine Auskunft über Parameter oder Anwendungen von speziellen Halbleitern. Viele tausend verschiedene Halbleitertypen sind heute erhältlich. Es ist fast unmöglich, auch nur einen geringen Prozentsatz aller Typen genau zu kennen. Somit bringen die meisten Ingenieure und Techniker nur die bekanntesten und gebräuchlichsten Halbleitertypen zur Anwendung, auch wenn neuere und bessere Elemente zur Verfügung stehen.

Um diesem Problem Abhilfe zu schaffen hat Motorola die meisten Halbleitertypen in eine Halbleitersammlung zusammengefasst. Diese Halbleitersammlung umfasst alle 1N, 2N und 3N Typen, die durch die "Electronics Industries Association" registriert sind. Weiterhin sind eine grosse Anzahl von Motorola In-Haus Typen in dieser Sammlung zusammengefasst. Vollständige Spezifikationen einer grossen Anzahl von diskreten Halbleitern und Kurzspezifikationen von integrierten Schaltkreisen sind vorhanden.

Zusätzlich sind, zur Vereinfachung der Aufsuche der meist gebrauchten Halbleitertypennummern, Nachschlagetabellen mit Vorzugstypen für bestimmte Anwendungen in der Sammlung enthalten.

Die Halbleitersammlung kann dem Entwicklungs und Komponent–Ingenieur sowie dem Einkäufer von Halbleitern gute Dienste leisten im Aufsuchen der best möglichen Elemente für eine bestimmte Anwendung.

ZUSAMMENSETZUNG DER HALBLEITERSAMMLUNG

Die Halbleitersammlung besteht aus drei Teilen, die folgendermassen zusammengefasst sind:

REFERENZ-BAND

Der Referenz-Band besteht aus einer übersichtlichen Zusammenfassung von Halbleitern und integrierten Schaltungen. Mit Hilfe dieses Referenzbandes lassen sich Halbleiter und integrierte Schaltungen für spezielle Anwendungszwecke leicht auffinden. Gehäuse–, Anwendungs– und Montagezubehörinformation sind ebenso im Referenzband angegeben. Nach der Wahl eines Halbleiters oder einer integrierten Schaltung aus dem Referenzband kann Band I oder Band II für die speziellen Daten zur Hilfe gezogen werden.

EIA Registriertes Halbleiter-Verzeichnis

Vollständiges numerisches Verzeichnis aller EIA registrierter Halbleiter Typen, mit den hauptsächlichen elektrischen Spezifikationen.

Nicht Registriertes Halbleiter-Verzeichnis

Vollständiges numerisches Verzeichnis aller nicht registrierter In-Haus Motorola Halbleiter Typen, mit den hauptsächlichen elektrischen Spezifikationen.

Mikroschaltkreis-Komponenten

Nicht eingekapselte Transistoren, Dioden, passive Elemente und integrierte Schaltkreise für den Gebrauch in hybriden Kreisen. (Prozess–, Einkapselung– und Inspektions-Kriterien sind inbegriffen.)

Hauptnachschlagewerk

Zusammenfassung in Gruppen der bevorzugten Hauptelementkategorien für schnelle Vorselektion der Elemente die am besten für gegebene Anwendungen in Frage kommen. Dieses Dokument enhält Halbleiterelemente und integrierte Kreise.

Militärelementen-Liste

Dies ist eine vollständige Liste von Motorola Bausteinen die Militärspezifikationen erfüllen.

Montagezubehör und Einkapselung Information

Bauelement-Montagezubehör, Kühlelemente und Spezial-Elementeneinkapselung.

Vermasste Elementen-Grundrisse

Vermasste Zeichnungen von Gehäusegrundrissen mit JEDEC und Motorola Gegenüberstellung. (Zeichnungen der Anschlussformen von gegebenen Gehäusen sind inbegriffen.)

Awendungsbericht-Katalog

Nachschlagliste der Anwendungsberichte welche in Anwendungskategorien zusammengefasst sind. Eine kurze Zusammenfassung des Inhalts der verfügbaren Berichte ist gegeben und ebenfalls wie sie bestellt werden können.

Um den Anforderungen eines praktischen, auf den letzten Stand gebrachten Nachschlagewerkes zu genügen wird der Referenz-Band der Halbleiterbibliothek zweimal im Jahr vollständig überarbeitet und publiziert. Zusätzliche Veröffentlichungen werden vierteljährlich herausgegeben.

BAND I

Dieser Band enthält vollständige Datenblätter der von Motorola fabrizierten Elemente mit EIA registrierten Nummern bis zu 1N4999 und 2N4999. Die Datenblätter sind in numerischer Ordnung gemäss der Bauelemente-Typennummer eingereiht. Ausnahme sind solche Datenblätter welche spezielle Elemente mit wechselnden Typennummern behandeln. Ein numerisches Verzeichnis am anfang des Bandes erlaubt dem Benützer ein schnelles Auffinden der Datenblätter für alle Elemente, die im Buch aufgeführt sind.

Weil die meisten Elemente-Typennummern in der Kategorie bis 5000 schon von bestehenden Produkten aufgebraucht wurden, ist erwartet, dass dieser Band in den nächsten Jahren wenig Ueberarbeitung verlangt. Dementsprechend wird dieses Buch nur neu gedruckt wenn die Nachfrage es verlangt und Modifikationen werden nur bei einer Neuauflage vorgenommen.

BAND II

Dieser Band enthält Datenblätter der von Motorola hergestellten EIA registrierten Elemente mit der Typennummer 1N5000 und 2N5000 und aufwärts und ebenfalls solche mit den 3N– – Typennummern. Alle aktiven Datenblätter für Elemente mit speziellen Motorola Typennummern (nicht EIA registriert) sind zusätzlich hier einbezogen.

Weil dieser Band die detaillierten Daten für alle der erst kürzlich entwickelten Halbleiter enthält, wird er durch Publikationen von Zusatzbüchern auf den letzten Stand gebracht. Zwei Zusatzbücher werden während der "Lebensdauer" dieser Ausgabe veröffentlicht werden.

Wie wird "Die Halbleiter Datenbibliothek" gebraucht

Die Bibliothek ist zusammengestellt worden um mehrere spezielle Funktionen zu erfüllen:

1. Erlaubt schnelle Bestimmung (zusammen mit Hauptspezifikationen) von EIA registrierten Halbleitern und Bausteinen mit speziellen Motorola Typennummern.
2. Erlaubt schnelle Selektion der best geeignetsten Elemente für eine bestimmte Schaltungsanwendung.
3. Erlaubt schnelle Selektion von Elementen welche am besten gegebene elektrische Spezifikationen erfüllen.
4. Liefert vollständige Charakterisation einer breiten Komponentenlinie, welche die meisten Halbleiter-Kategorien einschliesst. Erlaubt einen detaillierten Vergleich der Elementtypen.

Die nachfolgenden Beispiele veranschaulichen mehrere Wege um diese Bibliothek zu gebrauchen.

Problem: Elementen-Bestimmung
Bekannt: Elemente-Typennummer
Benötigte Information: Elementefunktion, Anwendung, Hauptspezifikationen

Vorgang: Im Hauptverzeichnis des Referenzbandes sind die Typennummern des zu untersuchenden Elementes in der alphanumerischen Liste aufgefuhrt. Die Information, die in diesem Verzeichnis gegeben ist, besteht nicht nur aus dem Elemententyp sondern auch die elektrischen Hauptspezifikationen sind gegeben. Zusätzlich ist angegeben ob das Element von Motorola hergestellt wird und, im Fall dass dies verneint wird, ob Motorola ein elektrisch vergleichbares Bauelement liefern kann. Wenn benötigt, können die vollständigen Daten der von Motorola hergestellten Halbleiter von den zwei anderen Bänden der Halbleiter Bibliothek erhalten werden.

Problem: Elementen-Vorbestimmung
Bekannt:

a) Vorgesehene Schaltkreisanwendung für ein bestimmtes Element.
b) Ungefähre elektrische Spezifikationen eines gewünschten Typs.

Benötigte Information:

a) Welche Elemente sind für eine bestimmte Kreisfunktion verfügbar?
b) Welche Elementtypen erfüllen am besten die erforderlichen elektrischen Charakteristiken?

Vorgang: Das Hauptnachschlagwerk des Referenzbandes wird aufgeschlagen. Dieses Kapitel enthält Produktkategorien, z.B. Leistungstransistoren, Zenerdioden etc. eingereiht in bestimmte Marktsegmente, einschliesslich Fernmeldewesen, Verbraucherindustrie und Militärbereich. Ein "Index" zu den einzelnen "Auswahl-Führern" ist am anfang dieses Kapitels gegeben, was zum schnellen Auffinden der zutreffenden "Führer" hilft. Vollständige Daten der von Motorola hergestellten Elemente können, wenn benötigt, von den zwei anderen Bänden entnommen werden.

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2N3285	↓
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2N3288	↓
2N3289	↓
2N3290	2-469
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2N3613	↓
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2N3804	↓
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2N3805	↓
2N3805A	↓
2N3806	↓
2N3807	↓
2N3808	↓
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2N4155	↓
2N4156	↓
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2N4158	↓
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2N4160	↓
2N4161	↓
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2N4168	↓
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2N4170	↓
2N4171	↓
2N4172	↓
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2N4179	↓
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2N4183	↓
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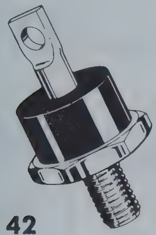
1N... JEDEC REGISTERED DEVICE SPECIFICATIONS

1N248B,C thru 1N250B,C

1N1191 thru 1N1198
1N1195A thru 1N1198A
1N3213,1N3214



CASE 42
(DO-5)

Medium current silicon rectifiers. Unique double-case construction consists of hermetically sealed inner metallic case surrounded by molded external case; provides highest degree of ruggedness and reliability. Type numbers shown have cathode connected to case, but reverse-polarity units can be obtained by adding suffix "R" to standard type number, e.g. 1N248BR.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage and DC Blocking Voltage	V_{RM} (rep) V_R		Volts
1N248B, 1N1191		50	
1N248C		55	
1N249B, 1N1192		100	
1N249C		110	
1N1193		150	
1N250B, 1N1194		200	
1N250C		220	
1N1195, 1N1195A		300	
1N1196, 1N1196A		400	
1N1197, 1N1197A, 1N3213		500	
1N1198, 1N1198A, 1N3214		600	
RMS Reverse Voltage	V_r		Volts
1N248B, 1N1191		35	
1N248C		38.5	
1N249B, 1N1192		70	
1N249C		77	
1N1193		105	
1N250B, 1N1194		140	
1N250C		154	
1N1195, 1N1195A		210	
1N1196, 1N1196A		280	
1N1197, 1N1197A, 1N3213		350	
1N1198, 1N1198A, 1N3214		420	
Average 1/2-Wave Rectified Forward Current (Resistive Load, 60 Hz , $T_C = 150^{\circ}C$)	I_O	20	Amp
Peak Repetitive Forward Current ($T_C = 150^{\circ}C$)	I_{FM} (rep)	90	Amp
Peak Surge Current ($T_C = 150^{\circ}C$, superimposed on Rated Current at Rated Voltage, 1/2-Cycle, 1/120 sec)	I_{FM} (surge)	350	Amp

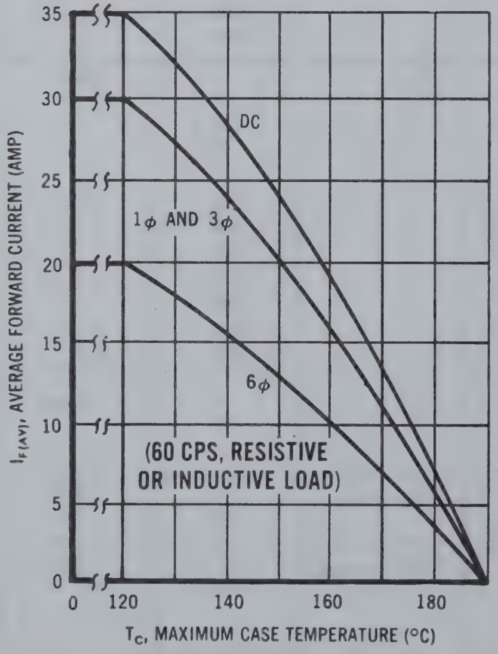
THERMAL CHARACTERISTICS

Maximum Operating and Storage Temperature: −65 to + 190°C
Maximum Thermal Impedance, Junction to Case: θ_{JC} = 1.50°C/W DC

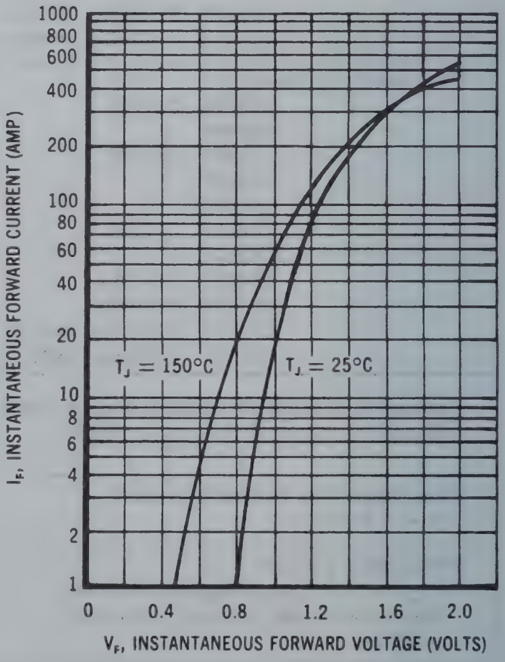
ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop ($I_{O\,(max)}$, rated V_r, 60 cps, T_C = 150°C)	$V_{F(AV)}$	0.6	Volts
Instantaneous Forward Voltage Drop (I_F = 100 Amps, T_J = 25°C)	V_F	1.5	Volts
Full Cycle Average Reverse Current ($I_{O\,(max)}$, rated V_r, 60 cps, T_C = 150°C)	$I_{R(AV)}$		mA
1N248B thru 1N250B, 1N1191 thru 1N1198		5.0	
1N248C		3.8	
1N249C		3.6	
1N250C		3.4	
1N1195A		3.2	
1N1196A		2.5	
1N1197A		2.2	
1N1198A		1.5	
1N3213 and 1N3214		10.0	
DC Reverse Current (Rated V_R, T_C = 25°C)	I_R	1.0	mA

MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM CASE TEMPERATURE



TYPICAL FORWARD CHARACTERISTICS



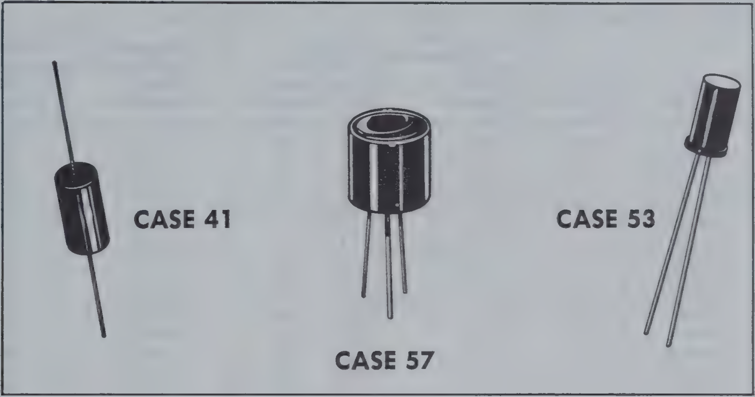
1N429

1N1530 series

1N1735 series

1N4057 series

Temperature compensated zener reference diodes designed for reference sources utilizing an oxide-passivated junction for long-term voltage stability, high uniformity and reliable operation.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Operating Junction Temperature Range	T_J	-55 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C
Power Dissipation*	P_D	See Tables 1 & 2*	W

*The devices are designed for operation at the specified I_{ZT}. Operation above or below this current is not recommended, since the temperature coefficient is no longer valid. See Note 2 and Figure 4.

MECHANICAL CHARACTERISTICS

Case:	Discrete glass package devices encapsulated in a transfer molded plastic package
Polarity:	Indicated by diode symbol except 1N429, 1N1530, 1N1530A where cathode indicated by polarity dot of contrasting color
Weight:	Varies according to device 0.5 grams (min) 12 grams (max)
Finish:	All external surfaces corrosion resistant and leads readily solderable.

TABLE 1 – ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

TYPE	CASE	Zener Voltage ±5% V_Z Volts	@ I_{ZT} mA	Z_{ZT} Ohms (Note 3)	Temperature Coefficient %/°C (Note 2)	ΔV_Z @ I_{ZT} (+25 to +100°C) Volts (Note 2)	ΔV_Z (–55 to + 25°C) Volts (Note 2)	P_D* T_A = 25°C W
1N4057	41-8	12.4	10	25	0.005	0.047	0.050	1.5
1N4057A		12.4		25	0.002	0.019	0.020	
1N4058		14.6		30	0.005	0.055	0.058	
1N4058A		14.6			0.002	0.022	0.023	
1N4059		16.8			0.005	0.063	0.067	
1N4059A		16.8			0.002	0.025	0.027	
1N4060		18.5			0.005	0.069	0.074	
1N4060A		18.5		↓	0.002	0.028	0.030	
1N4061		21		35	0.005	0.079	0.084	
1N4061A		21		35	0.002	0.032	0.034	
1N4062		23		40	0.005	0.086	0.092	
1N4062A		23		40	0.002	0.035	0.037	
1N4063		27		45	0.005	0.101	0.108	
1N4063A		27		45	0.002	0.041	0.043	
1N4064		30		50	0.005	0.113	0.120	
1N4064A		30		50	0.002	0.045	0.048	
1N4065		33		55	0.005	0.124	0.132	
1N4065A		33	↓	55	0.002	0.050	0.053	
1N4066		37	7.5	80	0.005	0.139	0.148	
1N4066A		37		80	0.002	0.056	0.059	
1N4067		43		90	0.005	0.161	0.172	
1N4067A		43		90	0.002	0.065	0.069	
1N4068		47		100	0.005	0.176	0.188	
1N4068A	↓	47		100	0.002	0.071	0.075	↓
1N4069	41-9	51		110	0.005	0.191	0.204	2.0
1N4069A		51		110	0.002	0.077	0.082	
1N4070		56		120	0.005	0.210	0.224	
1N4070A		56		120	0.002	0.084	0.090	
1N4071		62		135	0.005	0.232	0.248	
1N4071A		62	↓	135	0.002	0.093	0.099	
1N4072		68	5.0	230	0.005	0.255	0.272	
1N4072A		68		230	0.002	0.102	0.109	
1N4073		75		250	0.005	0.281	0.300	
1N4073A		75		250	0.002	0.113	0.120	
1N4074		82		270	0.005	0.307	0.328	
1N4074A		82		270	0.002	0.123	0.131	
1N4075		87		290	0.005	0.326	0.348	
1N4075A		87		290	0.002	0.131	0.139	
1N4076		91		310	0.005	0.341	0.364	
1N4076A		91		310	0.002	0.137	0.146	
1N4077		100		340	0.005	0.375	0.400	
1N4077A		100	↓	340	0.002	0.150	0.160	
1N4078		105	2.5	700	0.005	0.394	0.420	
1N4078A		105		700	0.002	0.158	0.168	
1N4079		110		740	0.005	0.413	0.440	
1N4079A		110		740	0.002	0.165	0.176	
1N4080		120		800	0.005	0.450	0.480	
1N4080A	↓	120		800	0.002	0.180	0.192	↓
1N4081	41-10	130		840	0.005	0.488	0.520	2.5
1N4081A		130		840	0.002	0.195	0.208	
1N4082		140		960	0.005	0.525	0.560	
1N4082A		140		960	0.002	0.210	0.224	
1N4083		150		1020	0.005	0.563	0.600	
1N4083A		150		1020	0.002	0.225	0.240	
1N4084		175		1150	0.005	0.656	0.700	
1N4084A		175		1150	0.002	0.263	0.280	
1N4085		200		1350	0.005	0.750	0.800	
1N4085A	↓	200	↓	1350	0.002	0.300	0.320	↓

*Derate linearly from 25°C to 175°C.

1N429/1N1530/1N1735/1N4057 (continued)

TABLE 2 – ELECTRICAL CHARACTERISTICS (I_{ZT} = 7.5 mA, T_A = 25°C unless otherwise noted)

Type Number	Zener Voltage $V_Z \pm 5\%$ (Volts)	Max Voltage Change @ –55, +25, +100°C ΔV_Z (Volts) (Note 2)	Max Dynamic Impedance (Note 3) Z_{ZT} (Ohms)	Temperature Coefficient (Note 2) (%/°C)	Power* Dissipation P_D (mW)	Case Number	Figure Number
1N429 ①	6.2	0.050	20	0.01	200	53	1
1N1735	6.2	0.050	20	0.01	200	41-6	2
1N1530** 1N1530A** ②	8.4	0.014 0.007	15	0.002 0.001	250	57	3
1N1736 1N1736A	12.4	0.100 0.050	40	0.01 0.005	400	41-3	2
1N1737 1N1737A	18.6	0.150 0.075	60	0.01 0.005	600	41-5	2
1N1738 1N1738A	24.8	0.200 0.100	80	0.01 0.005	800	41-5	2
1N1739 1N1739A	31.0	0.250 0.125	100	0.01 0.005	1000	41-4	2
1N1740 1N1740A	37.2	0.300 0.150	120	0.01 0.005	1200	41-4	2
1N1741 1N1741A	43.4	0.350 0.175	140	0.01 0.005	1400	41-4	2
1N1742 1N1742A ③	49.6	0.400 0.200	180	0.01 0.005	1600	41-4	2

*Derate linearly from 25°C to 175°C

**I_{ZT} = 10 mA

① Available to MIL-S-19500/299 Specifications.

② Available to MIL-S-19500/320 Specifications.

③ Available to MIL-S-19500/298 Specifications.

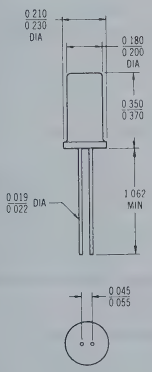
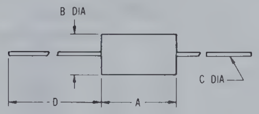

0 210
0 230
DIA
0 180
0 200
DIA
0 350
0 370
0 019
0 022
DIA
1 062
MIN
0 045
0 055

FIGURE 1
CASE 53


B DIA
C DIA
D
A

PKG.	OUTLINE DIMENSIONS (INCHES)			
	A MAX	B MAX	C ± 0.002	D MIN
41 1	1.00	0.500	0.032	1.25
41-2	0.500	0.375	0.032	1.25
41-3	1.030	0.378	0.032	1.25
41-4	1.220	0.641	0.032	1.75
41-5	0.655	0.641	0.032	1.25
41-6	0.520	0.275	0.020	1.25
41-7	1.000	0.375	0.032	1.25
41-8	0.520	0.260	0.030	1.00
41-9	0.780	0.260	0.030	1.00
41 10	1.155	0.323	0.030	1.00

FIGURE 2
CASE 41

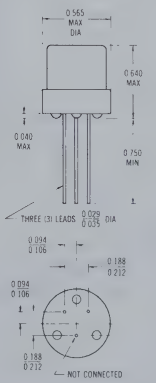

0 565
MAX
DIA
0 640
MAX
0 040
MAX
0 750
MIN
THREE (3) LEADS
0 029
0 035
DIA
0 094
0 106
0 188
0 212
0 094
0 106
0 188
0 212
NOT CONNECTED

FIGURE 3
CASE 57

TEMPERATURE-COMPENSATED REFERENCE DIODES

Temperature compensated reference diodes are made possible by taking advantage of the differing thermal characteristics of forward and reverse biased silicon PN junctions. A forward biased junction has a negative temperature coefficient of approximately 2.0 millivolts/°C. Reverse biased junctions above 5.0 volts have a positive temperature coefficient and therefore it is possible by judicious selection of combinations of forward and reverse biased junctions to obtain a device which shows a very low temperature coefficient due to cancellation. Because of the differing impedance versus temperature characteristics of the junctions involved, optimum temperature stability is obtained by operating in the zener current range at which the temperature coefficient is a minimum (Figure 4)

Further information, including a method of effective impedance cancellation in a bridge circuit for ultra-stable reference supplies, is contained in the Zener Diode Handbook. The handbook, containing valuable theory, design, and application information, is available from your distributor.

NOTE 1 — Voltage-Current Characteristics

Figure 4 shows the voltage-current characteristics of a typical temperature compensated unit at three different temperatures. The exploded view illustrates the cross-over area (optimum temperature stability point), the non-linearity of the temperature-voltage relationship, and the maximum voltage variation (ΔV_Z) for the three temperatures shown.

Because of device impedance, the reference voltage will vary with changes in zener current. These variations can be minimized by driving the device from a constant current source.

NOTE 2 — Voltage Variation (ΔV_Z) and Temperature Coefficient

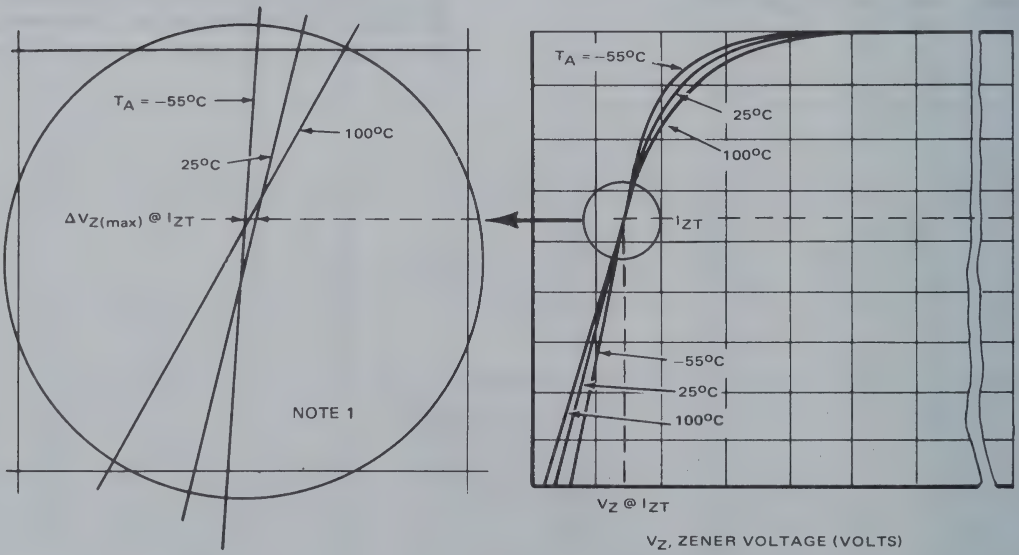
All reference diodes are characterized by the "box" method. This method provides for a guaranteed maximum voltage variation (ΔV_Z in mV) over a specified temperature range at the specified I_{ZT} verified by tests at several points within the range. (Maximum voltage variations over the specified temperature ranges are given in Tables 1 and 2.) The design engineer now has a number (without any calculations) telling him the stability of the voltage over the temperature range of interest thus giving him the maximum flexibility as well as economy in selecting the temperature stability required. The referenced military specifications use this approach to characterize these devices.

Since reference diodes have a non-linear voltage-temperature relationship (illustrated in exploded view, Figure 4) the temperature coefficients in %/°C are tabulated primarily for reference purposes and are guaranteed only at the end points of the temperature range.

NOTE 3 — Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60 Hz ac voltage which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

FIGURE 4 — TYPICAL OPERATING CHARACTERISTICS



1N702 thru 1N745 (ZENER DIODES)

CASE 51
(DO-7)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N5221 series.

1/4 watt, 2-200 volts

1N746 thru 1N759 1N746A thru 1N759A (ZENER DIODES)
1N4370 thru 1N4372 1N4370A thru 1N4372A

CASE 51

Hermetically sealed, all-glass case with all external surfaces corrosion resistant.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C
D C Power Dissipation: 400 Milliwatts at 50°C Ambient (Derate 3.2 mW/°C Above 50°C Ambient)

TOLERANCE DESIGNATIONS

The type numbers shown haye tolerance designations as follows:

1N4370 series: ±10%, suffix A for ±5% units.
1N746 series: ±10%, suffix A for ±5% units.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

TYPE NUMBER	NOMINAL ZENER VOLTAGE V_Z @ I_{ZT} VOLTS	TEST CURRENT I_{ZT} mA	MAXIMUM ZENER IMPEDANCE Z_{ZT} @ I_{ZT} Ohms	MAXIMUM DC ZENER CURRENT I_{ZM} mA	MAXIMUM REVERSE LEAKAGE CURRENT $T_A = 25°C$ I_R @ $V_R = 1$ V μA	$T_A = 150°C$ I_R @ $V_R = 1$ V μA
1N4370	2.4	20	30	150	100	200
1N4371	2.7	20	30	135	75	150
1N4372	3.0	20	29	120	50	100
1N746	3.3	20	28	110	10	30
1N747	3.6	20	24	100	10	30
1N748	3.9	20	23	95	10	30
1N749	4.3	20	22	85	2	30
1N750	4.7	20	19	75	2	30
1N751	5.1	20	17	70	1	20
1N752	5.6	20	11	65	1	20
1N753	6.2	20	7	60	0.1	20
1N754	6.8	20	5	55	0.1	20
1N755	7.5	20	6	50	0.1	20
1N756	8.2	20	8	45	0.1	20
1N757	9.1	20	10	40	0.1	20
1N758	10.0	20	17	35	0.1	20
1N759	12.0	20	30	30	0.1	20

POLARITY: Cathode End, Indicated by Color Band, Will Be Positive When Operate Operated In The Zener Region.

1N746 thru 1N759 (continued)

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

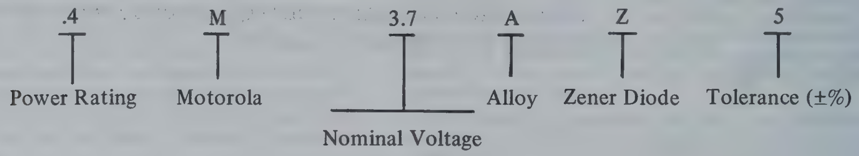
1 – Nominal zener voltages between those shown.

2 – Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  - a Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  - b. Two or more units matched to one another with any specified tolerance.

3 – Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

To designate units with zener voltages other than those listed, the Motorola type number should be modified as shown below. Unless otherwise specified, the electrical characteristics other than the nominal voltage (V_Z) and test voltage for leakage current will conform to the characteristics of the next higher voltage type shown in the table.

EXAMPLE: 1N746 series, 1N4370 series



1N761 thru 1N769

Recommended for applications requiring an exact replacement only. For new designs see 1N5221 series.

.4M.64FR10/1N816
.4M1.36FR5
.4M1.36FR2
.4M2.04FR5
.4M2.04FR2
MZ2360
MZ2361
MZ2362

CONSTANT-VOLTAGE REFERENCE DIODES FOR LOW-VOLTAGE APPLICATIONS

. . . high-conductance silicon diodes designed as a stable forward reference source for biasing transistor amplifiers and similar applications.

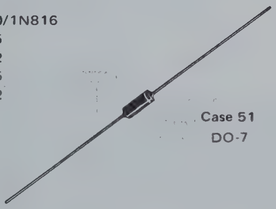
- Guaranteed Forward Voltage Range
- Choice of Package
- Temperature Effects Provided

FORWARD REFERENCE DIODES
– STABISTORS –

MAXIMUM RATINGS

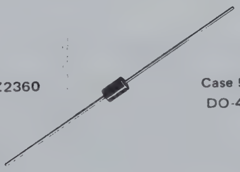
Rating	Symbol	Value	Unit
DC Power Dissipation @ $T_L = 30^oC \pm 3^oC$, Lead Length = 3/8″	P_D	400	mW
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	^oC

.4M.64FR10/1N816
.4M1.36FR5
.4M1.36FR2
.4M2.04FR5
.4M2.04FR2
MZ2361
MZ2362



Case 51
DO-7

MZ2360



Case 59
DO-41

MECHANICAL CHARACTERISTICS

Case: Choice of package, either Glass or Surmetic

Dimensions: See outline drawings

Finish: All external surfaces are corrosion resistant and leads are readily solderable and weldable

Polarity: Cathode indicated by polarity band. Cathode negative for forward reference application.

Weight: 0.2 Gram (approximate)

Mounting Positions: Any

.4M.64FR10/1N816,.4M1.36FR5, .4M1.36FR2, .4M2.04FR5, .4M2.04FR2, MZ2360, MZ2361, MZ2362 (continued)

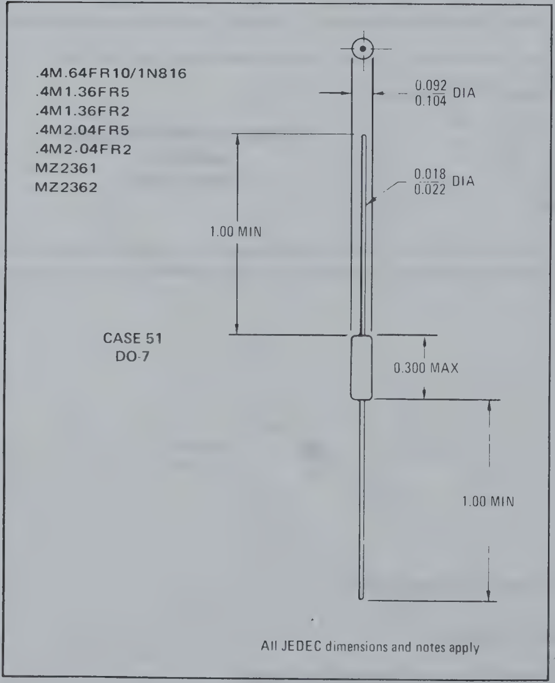
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Type Number	Forward Reference Voltage (1) @ V_F Volts Min/Max	I_F mA	Reverse Leakage Current (Max) @ I_R μA	V_R Volts	Package	Case
.4M.64FR10/ 1N816* (2)	0.58/0.70	1.0	0.1	4.0	Glass	51
.4M1.36FR5	1.29/1.43	10	0.1	4.0	Glass	51
.4M1.36FR2	1.33/1.39	10	0.1	4.0	Glass	51
.4M2.04FR5	1.94/2.14	10	0.1	4.0	Glass	51
.4M2.04FR2	2.00/2.08	10	0.1	4.0	Glass	51
MZ2360	0.63/0.71	10	10	5.0	Surmetic	59
MZ2361	1.24/1.38	10	10	5.0	Surmetic	51
MZ2362	1.90/2.10	10	10	5.0	Glass	51

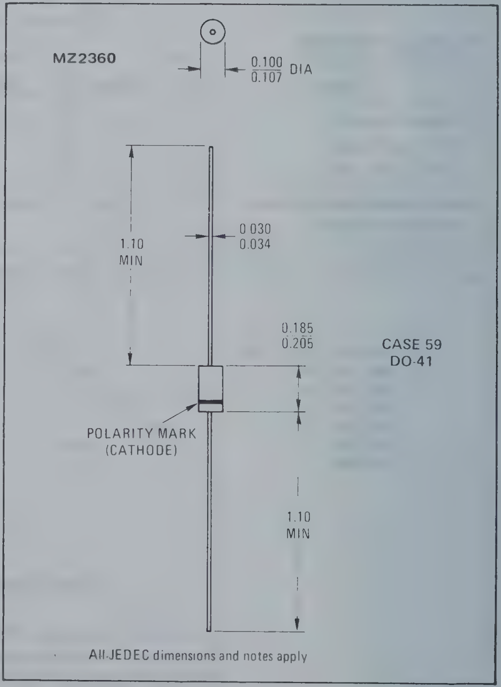
*Indicates JEDEC Registered Data for 1N816

(1) Motorola guarantees the forward reference voltage when measured at 90 seconds while maintaining the lead temperature (T_L) at 30°C ± 1°C, 3/8" from the diode body.

(2) Minimum Saturation Voltage for 1N816 = 40 V @ 100 μA.


.4M.64FR10/1N816
.4M1.36FR5
.4M1.36FR2
.4M2.04FR5
.4M2.04FR2
MZ2361
MZ2362
0.092 / 0.104 DIA
0.018 / 0.022 DIA
1.00 MIN
CASE 51
DO-7
0.300 MAX
1.00 MIN

All JEDEC dimensions and notes apply


MZ2360
0.100 / 0.107 DIA
1.10 MIN
0.030 / 0.034
0.185 / 0.205
CASE 59
DO-41
POLARITY MARK (CATHODE)
1.10 MIN

All JEDEC dimensions and notes apply

.4M.64FR10/1N816, .4M1.36FR5, .4M1.36FR2, .4M2.04FR5, .4M2.04FR2, MZ2360, MZ2361, MZ2362 (continued)

TYPICAL FORWARD VOLTAGE CHARACTERISTICS

FIGURE 1 — .4M.64FR10/1N816

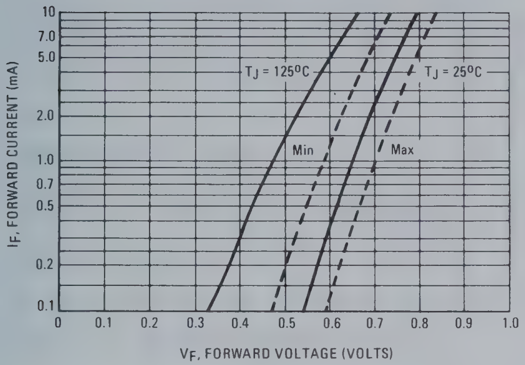


FIGURE 2 — .4M1.36FR5

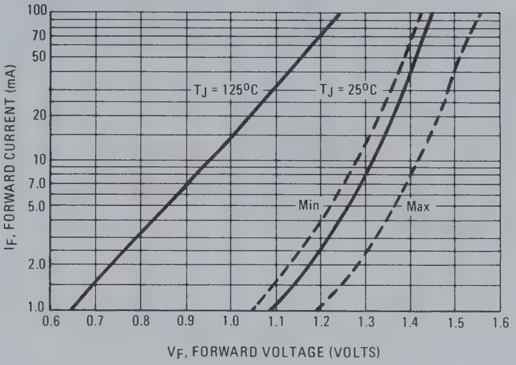


FIGURE 3 — .4M2.04FR5

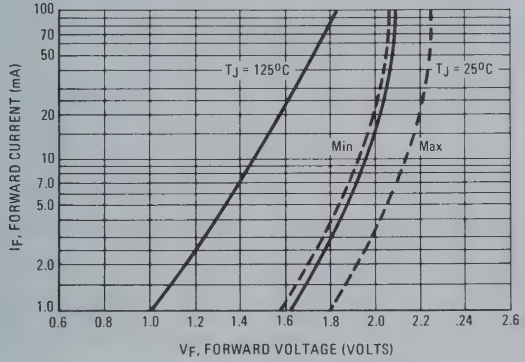


FIGURE 4 — MZ2360

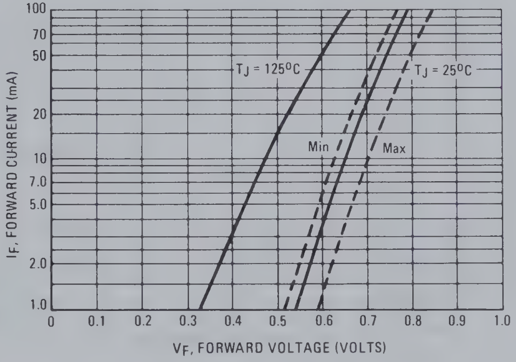


FIGURE 5 — MZ2361

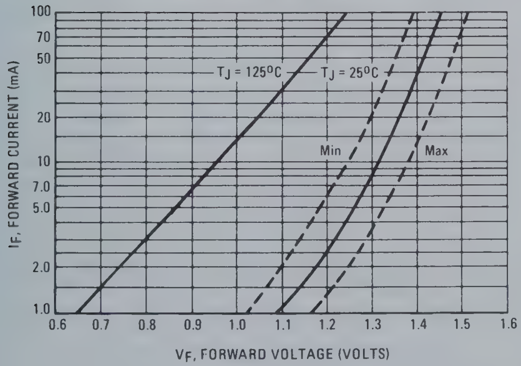
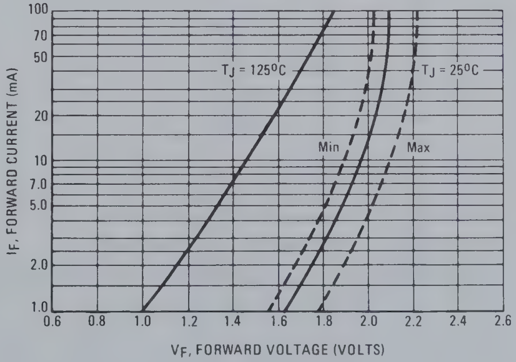


FIGURE 6 — MZ2362



.4M.64FR10/1N816, .4M1.36FR5, .4M1.36FR2, .4M2.04FR5, .4M2.04FR2, MZ2360, MZ2361, MZ2362 (continued)

TYPICAL TEMPERATURE COEFFICIENT

FIGURE 7 – .4M.64FR10/1N816

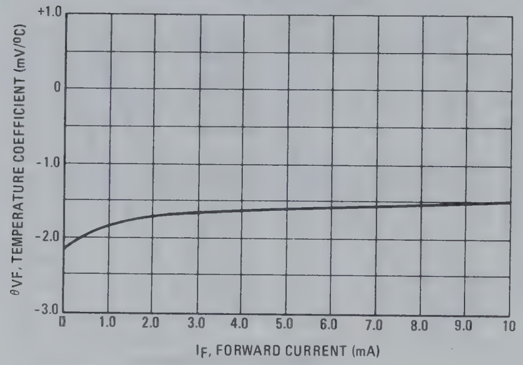


FIGURE 8 – MZ2360

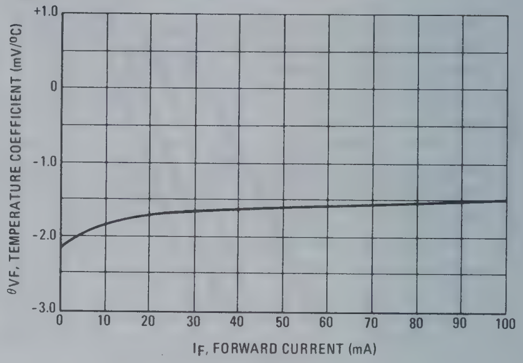


FIGURE 9 – .4M1.36FR5/MZ2361

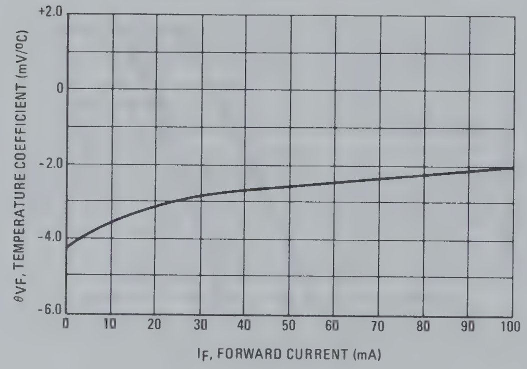
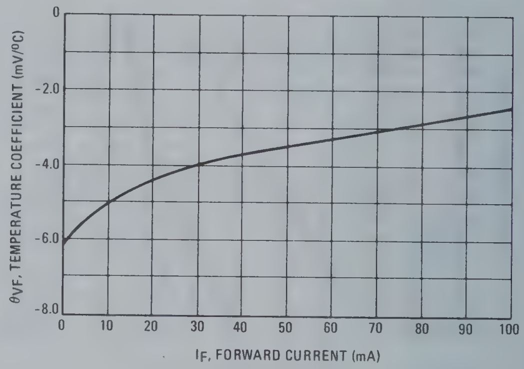


FIGURE 10 – .4M2.04FR5/MZ2362



1N821, A, 1N823, A (SILICON)
1N825, A, 1N827, A
1N829, A

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 400 mW @ $T_A = 50^\circ C$

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

$V_Z = 6.2$ V ±5.0%* @ $I_{ZT} = 7.5$ mA

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Ambient Test Temperature °C ±1°C	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} Ohms (Note 3)
1N821	0.096	-55, 0, +25, +75, +100 ↓	0.01	15 ↓
1N823	0.048		0.005	
1N825	0.019		0.002	
1N827	0.009		0.001	
1N829	0.005		0.0005	
1N821A	0.096		0.01	10 ↓
1N823A	0.048		0.005	
1N825A	0.019		0.002	
1N827A	0.009		0.001	
1N829A	0.005		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 30 to 400 pF @ 90% of V_Z

FORWARD BREAKDOWN VOLTAGE (V_f) = 15 to 400 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N821 thru 1N829

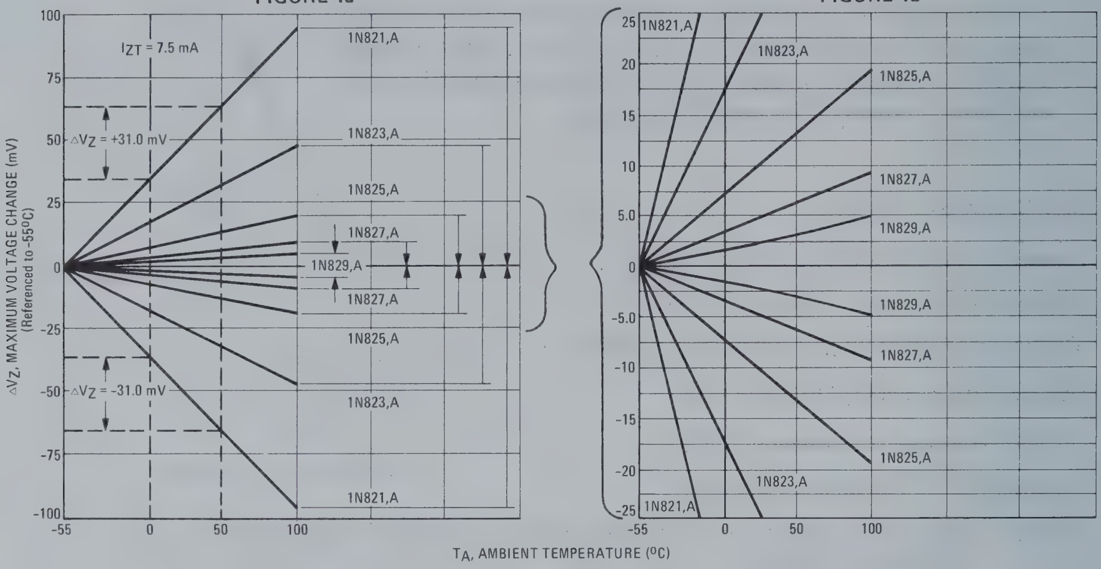


FIGURE 1a

FIGURE 1b

ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE

(At Specified Temperatures)
(See Note 5)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES.

FIGURE 2 — 1N821 SERIES

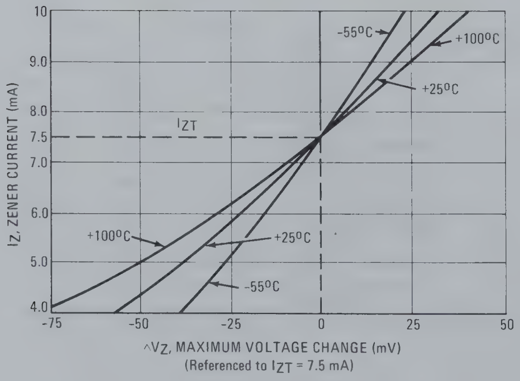
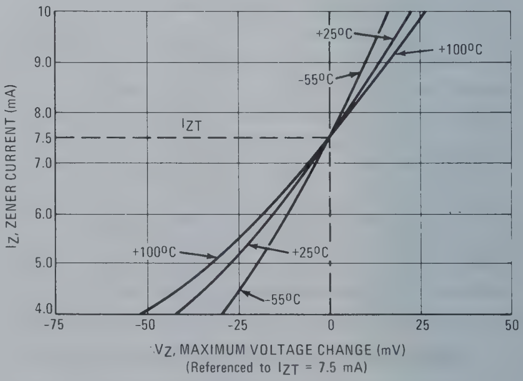


FIGURE 3 — 1N821A SERIES



1N821,A / 1N823,A / 1N825,A / 1N827,A / 1N829,A (continued)

MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 3)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES.

FIGURE 4 – 1N821 SERIES

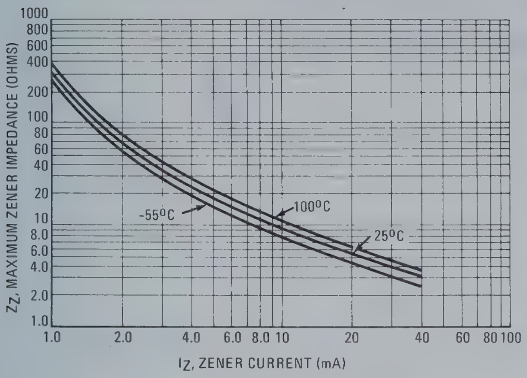


FIGURE 5 – 1N821A SERIES

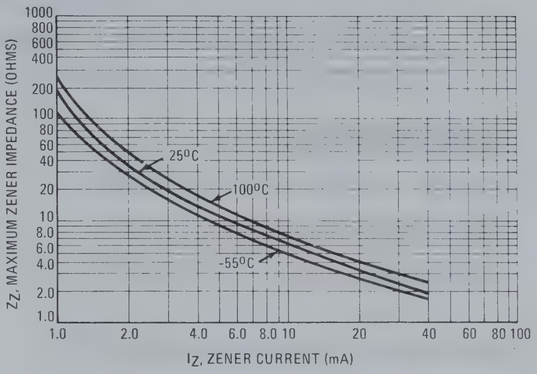
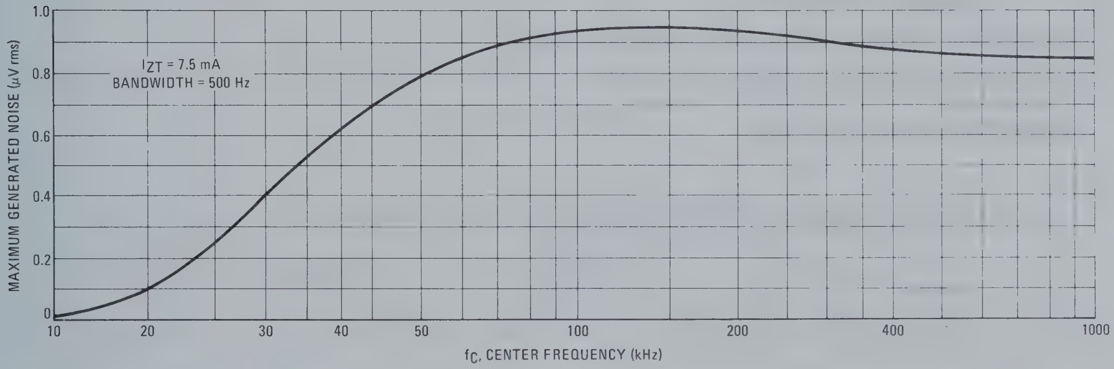


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N821, 1N823, 1N825, 1N827, and 1N829 are available to MIL-S-19500/159.

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the maximum ΔV_Z given. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figures 4 and 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

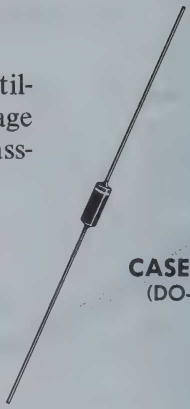
These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from 0 to +50°C will cause a voltage change no greater than +31 mV or –31 mV for 1N821 or 1N821A, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, an expanded view of the shaded area in Figure 1a is shown in Figure 1b.

NOTE 5:

The maximum voltage change, ΔV_Z, Figures 2 and 3 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by graphically adding ΔV_Z in Figure 2 or 3 to the ΔV_Z in Figure 1 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 2 or 3 on Figure 1. For a more detailed explanation see AN-437 (Application Note).

1N935, A, B (SILICON)
thru
1N939, A, B

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.



CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 500 mW @ $T_A = 25^oC$

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Ambient Test Temperature °C ±1°C	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 9.0 V ±5.0%* @ I_{ZT} = 7.5 mA				
1N935	0.067	0, +25, +75	0.01	20
1N936	0.033		0.005	
1N937	0.013		0.002	
1N938	0.006		0.001	
1N939	0.003		0.0005	
1N935A	0.139	-55, 0, +25, +75, +100	0.01	20
1N936A	0.069		0.005	
1N937A	0.027		0.002	
1N938A	0.013		0.001	
1N939A	0.007		0.0005	
1N935B	0.184	-55, 0, +25, +75, +100, +150	0.01	20
1N936B	0.092		0.005	
1N937B	0.037		0.002	
1N938B	0.018		0.001	
1N939B	0.009		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 20 to 180 pF @ 90% of V_Z

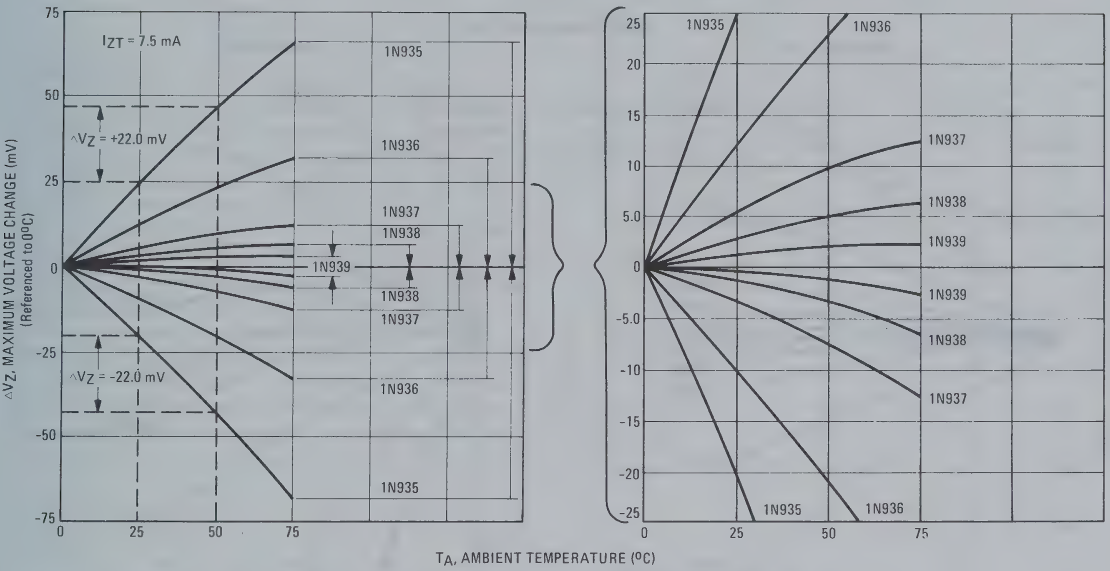
FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935 thru 1N939

FIGURE 1a FIGURE 1b

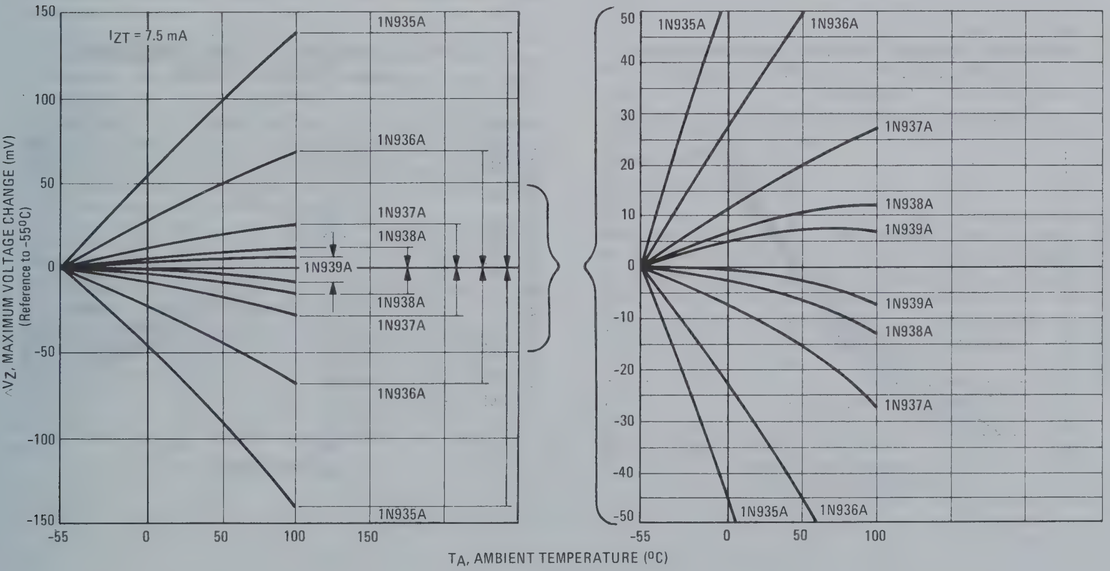


MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935A thru 1N939A

FIGURE 2a FIGURE 2b



MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935B thru 1N939B

FIGURE 3a

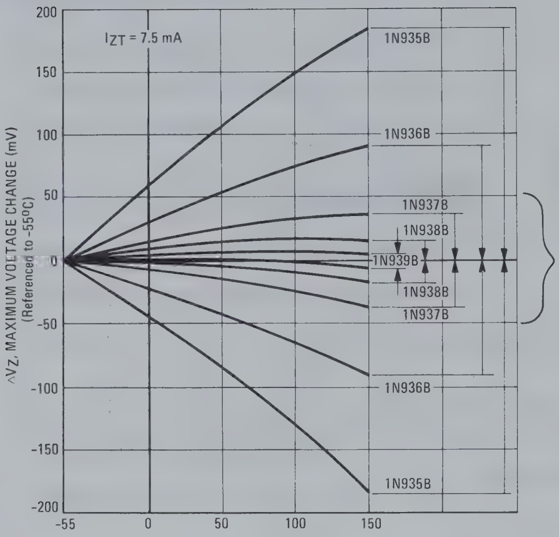
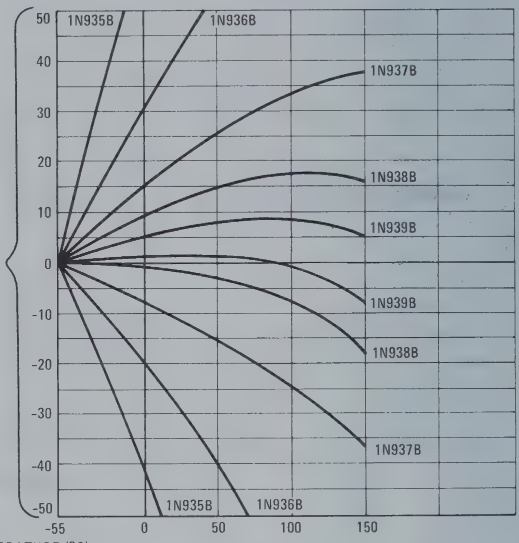


FIGURE 3b



T_A, AMBIENT TEMPERATURE (°C)

FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)

(See Note 5)

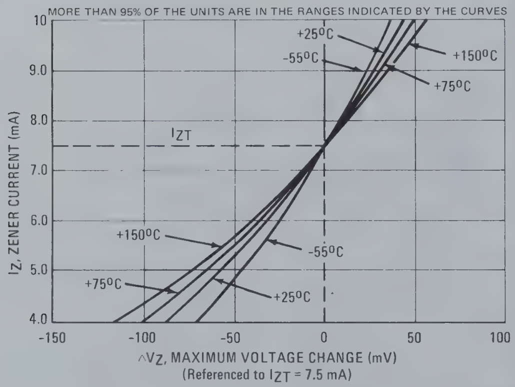


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 3)

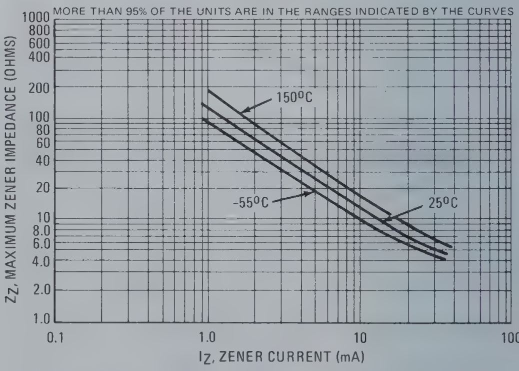
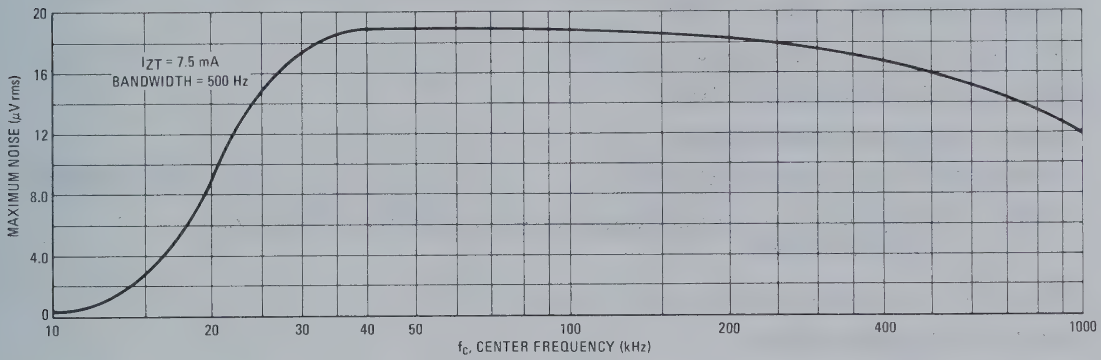


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N935B, 1N937B, and 1N939B are available to MIL-S-19500/156.

NOTE 2:

Voltage Variation ($\triangle V_Z$) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation ($\triangle V_Z$) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +22 mV or −22 mV for 1N935, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 5:

The maximum voltage change, $\triangle V_Z$, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding $\triangle V_Z$ in Figure 4 to the $\triangle V_Z$ in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

1N941, A, B (SILICON)
thru
1N945, A, B

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: –55 to +175°C

Storage Temperature: –65 to +175°C

DC Power Dissipation: 500 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Ambient Test Temperature °C ±1°C	Temperature Coefficient %/°C (Note 2)	Maximum Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 11.7 V ±5.0%* @ I_{ZT} = 7.5 mA				
1N941	0.088	0, +25, +75	0.01	30
1N942	0.044		0.005	
1N943	0.018		0.002	
1N944	0.009		0.001	
1N945	0.004		0.0005	
1N941A	0.181	-55, 0, +25, +75, +100	0.01	30
1N942A	0.090		0.005	
1N943A	0.036		0.002	
1N944A	0.018		0.001	
1N945A	0.009		0.0005	
1N941B	0.239	-55, 0, +25, +75, +100, +150	0.01	30
1N942B	0.120		0.005	
1N943B	0.047		0.002	
1N944B	0.024		0.001	
1N945B	0.012		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 14 to 35 pF @ 90% of V_Z

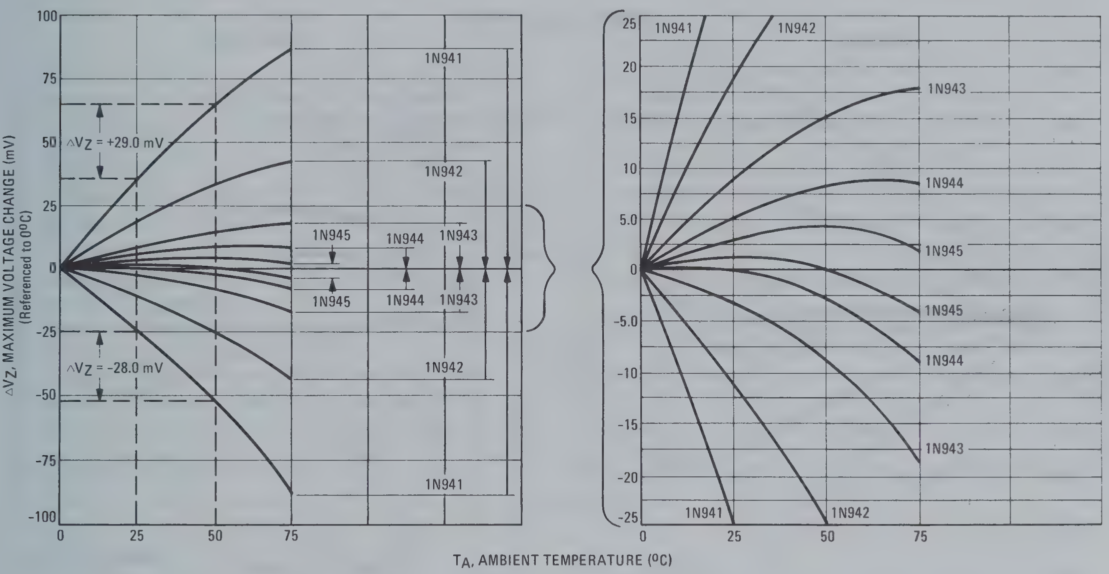
FORWARD BREAKDOWN VOLTAGE (V_f) = 150 to 1200 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941 thru 1N945

FIGURE 1a FIGURE 1b

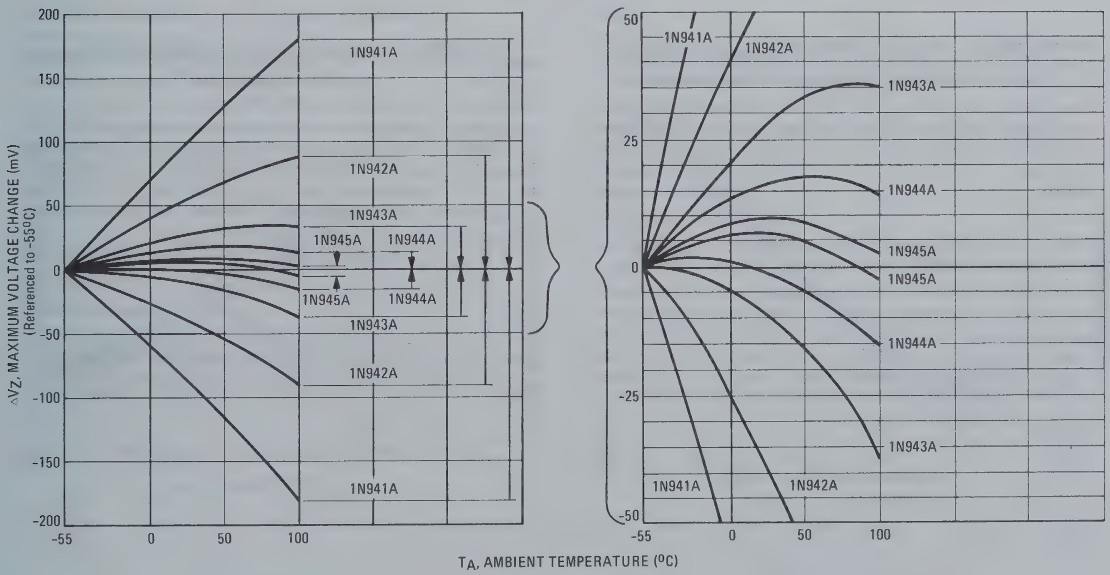


MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941A thru 1N945A

FIGURE 2a FIGURE 2b



MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941B thru 1N945B

FIGURE 3a **FIGURE 3b**

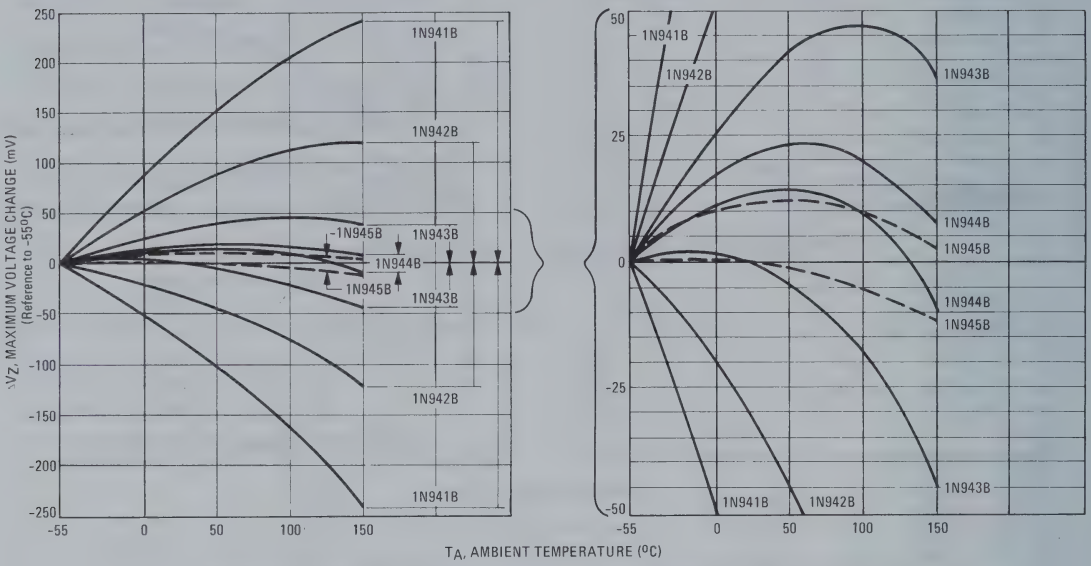


FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (At specified temperatures)

(See Note 5)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

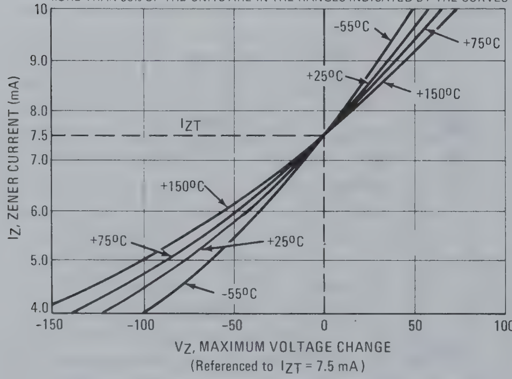


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 3)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

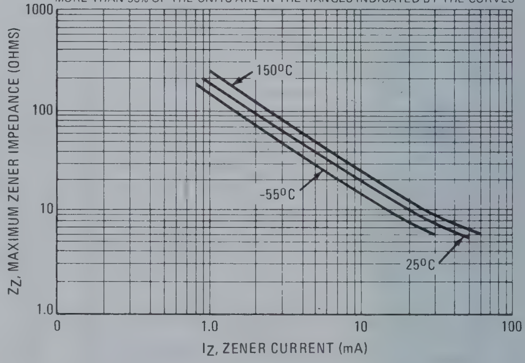
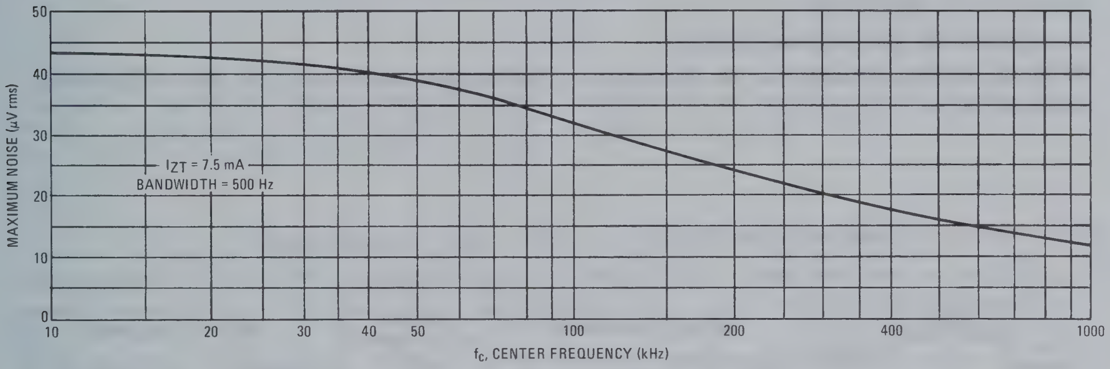


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N941B, 1N943B, and 1N944B are available to MIL-S-19500/157.

NOTE 2:

Voltage Variation ($\triangle V_Z$) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation ($\triangle V_Z$) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability — by means of temperature coefficient — accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +29 mV or -28 mV for 1N941, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 5:

The maximum voltage change, $\triangle V_Z$, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding $\triangle V_Z$ in Figure 4 to the $\triangle V_Z$ in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

1N957 thru 1N992

CASE 51
(DO-7)

Hermetically sealed, all-glass case with all external surfaces corrosion resistant. Cathode end, indicated by color band, will be positive with respect to anode end when operated in the zener region.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C

D C Power Dissipation: 400 Milliwatts at 50°C Ambient (Derate 3.2 mW/°C Above 50°C Ambient)

TOLERANCE DESIGNATIONS

With no suffix, tolerance is ±20%, for ±10% units, add suffix A, for ±5% units, add suffix B.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Motorola Guarantees the Zener Voltage at 90 Seconds with Lead Temperature of 30°C±1°C, 3/8" from Unit Body.

TYPE NUMBER	NOMINAL ZENER VOLTAGE V_Z VOLTS	TEST CURRENT I_{ZT} mA	MAXIMUM ZENER IMPEDANCE			MAXIMUM DC ZENER CURRENT I_{ZM} mA	REVERSE LEAKAGE CURRENT		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R MAXIMUM (μA)	TEST VOLTAGE Vdc * V_{R1}	V_{R2}
1N957	6.8	18.5	4.5	700	1.0	47	150	5.2	4.9
1N958	7.5	16.5	5.5	700	0.5	42	75	5.7	5.4
1N959	8.2	15	6.5	700	0.5	38	50	6.2	5.9
1N960	9.1	14	7.5	700	0.5	35	25	6.9	6.6
1N961	10	12.5	8.5	700	0.25	32	10	7.6	7.2
1N962	11	11.5	9.5	700	0.25	28	5	8.4	8.0
1N963	12	10.5	11.5	700	0.25	26	5	9.1	8.6
1N964	13	9.5	13	700	0.25	24	5	9.9	9.4
1N965	15	8.5	16	700	0.25	21	5	11.4	10.8
1N966	16	7.8	17	700	0.25	19	5	12.2	11.5
1N967	18	7.0	21	750	0.25	17	5	13.7	13.0
1N968	20	6.2	25	750	0.25	15	5	15.2	14.4
1N969	22	5.6	29	750	0.25	14	5	16.7	15.8
1N970	24	5.2	33	750	0.25	13	5	18.2	17.3
1N971	27	4.6	41	750	0.25	11	5	20.6	19.4
1N972	30	4.2	49	1000	0.25	10	5	22.8	21.6
1N973	33	3.8	58	1000	0.25	9.2	5	25.1	23.8
1N974	36	3.4	70	1000	0.25	8.5	5	27.4	25.9
1N975	39	3.2	80	1000	0.25	7.8	5	29.7	28.1
1N976	43	3.0	93	1500	0.25	7.0	5	32.7	31.0
1N977	47	2.7	105	1500	0.25	6.4	5	35.8	33.8
1N978	51	2.5	125	1500	0.25	5.9	5	38.8	36.7
1N979	56	2.2	150	2000	0.25	5.4	5	42.6	40.3
1N980	62	2.0	185	2000	0.25	4.9	5	47.1	44.6
1N981	68	1.8	230	2000	0.25	4.5	5	51.7	49.0
1N982	75	1.7	270	2000	0.25	4.0	5	56.0	54.0
1N983	82	1.5	330	3000	0.25	3.7	5	62.2	59.0
1N984	91	1.4	400	3000	0.25	3.3	5	69.2	65.5
1N985	100	1.3	500	3000	0.25	3.0	5	76.0	72.0
1N986	110	1.1	750	4000	0.25	2.7	5	83.6	79.2
1N987	120	1.0	900	4500	0.25	2.5	5	91.2	86.4
1N988	130	0.95	1100	5000	0.25	2.3	5	98.8	93.6
1N989	150	0.85	1500	6000	0.25	2.0	5	114.0	108.0
1N990	160	0.80	1700	6500	0.25	1.9	5	121.6	115.2
1N991	180	0.68	2200	7100	0.25	1.7	5	136.8	129.6
1N992	200	0.65	2500	8000	0.25	1.5	5	152.0	144.0

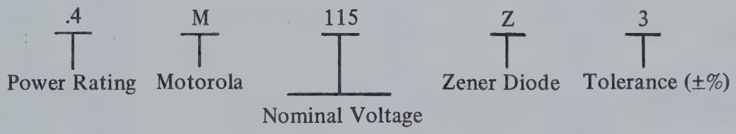
1N957 thru 1N992 (continued)

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)
1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

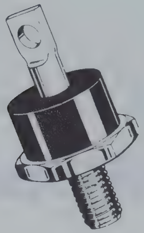
***V_{R1} — Test Voltage for 5% Tolerance Device**
V_{R2} — Test Voltage for 10% Tolerance Device
No Leakage Specified as 20% Tolerance Device

To designate units with zener voltages other than those listed, the Motorola type number should be modified as shown below. Unless otherwise specified, the electrical characteristics other than the nominal voltage (V_Z) and test voltage for leakage current will conform to the characteristics of the next higher voltage type shown in the table.

EXAMPLE: 1N957 series



1N1183 thru 1N1190 (SILICON)



CASE 42
(DO-5)

Medium current silicon rectifiers. Unique double-case construction consists of hermetically sealed inner metallic case surrounded by molded external case; provides highest degree of ruggedness and reliability. Type numbers shown have cathode connected to case, but reverse-polarity units can be obtained by adding suffix "R" to standard type number, e.g. 1N1183R.

MAXIMUM RATINGS

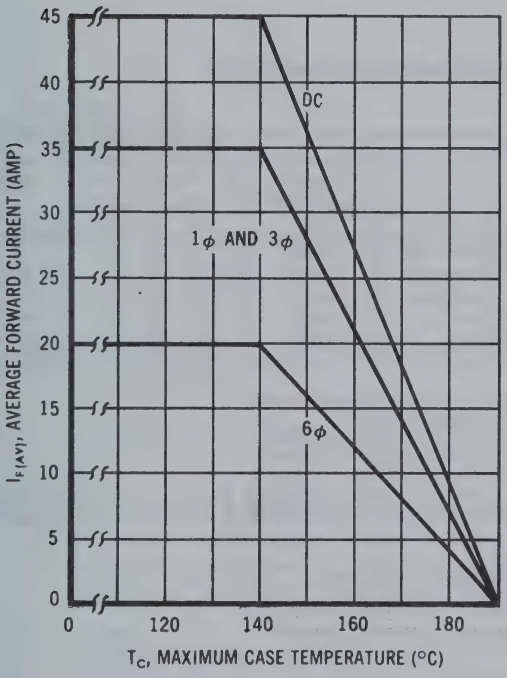
Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage and DC Blocking Voltage	$V_{RM\,(rep)}$ V_R		Volts
1N1183		50	
1N1184		100	
1N1185		150	
1N1186		200	
1N1187		300	
1N1188		400	
1N1189		500	
1N1190		600	
RMS Reverse Voltage	V_r		Volts
1N1183		35	
1N1184		70	
1N1185		105	
1N1186		140	
1N1187		210	
1N1188		280	
1N1189		350	
1N1190		420	
Average 1/2-Wave Rectified Forward Current (Resistive Load, 60 Hz, T_C = 140°C)	I_O	35	Amp
Peak Repetitive Forward Current (T_C = 140°C)	$I_{FM\,(rep)}$	150	Amp
Peak Surge Current (T_C = 140°C, superimposed on Rated Current at Rated Voltage)	$I_{FM\,(surge)}$	400	Amp
Operating and Storage Temperature	T_J, T_{stg}	-65 to +190	°C
Thermal Impedance	θ_{JC}	1.0	°C/W, DC steady state

1N1183 thru 1N1190 (continued)

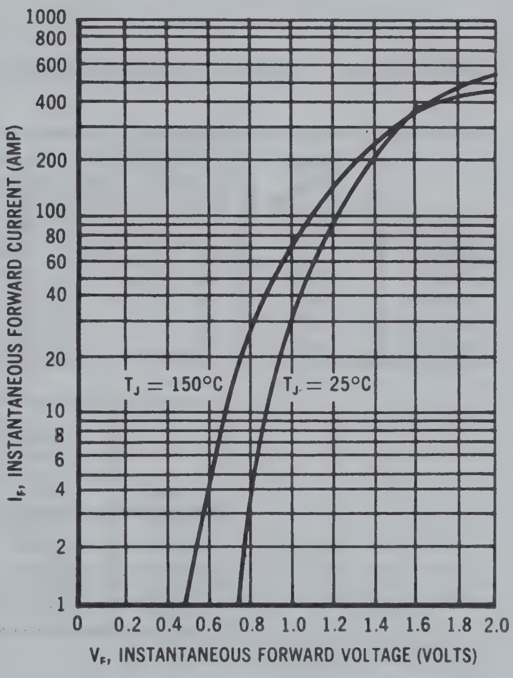
ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Value	Unit
Max Full Cycle Average Forward Voltage Drop ($I_{O\,(max)}$, rated V_r, 60 Hz, T_C = 140°C)	$V_{F(AV)}$	0.6	Volts
Max Instantaneous Forward Voltage Drop (I_F = 100 Amps, T_J = 25°C)	V_F	1.3	Volts
Max Full Cycle Average Reverse Current ($I_{O\,(max)}$, rated V_r, 60 Hz, T_C = 140°C)	$I_{R(AV)}$	10.0	mA
Max DC Reverse Current (Rated V_R, T_C = 25°)	I_R	1.0	mA

MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM CASE TEMPERATURE (60 CPS, RESISTIVE OR INDUCTIVE LOAD)



TYPICAL FORWARD CHARACTERISTICS



1N1191 thru 1N1198
1N1195A thru 1N1198A

For Specifications, See **1N248B** Data.

1N1313 thru 1N1327

CASE 53

Very low power zener diodes with standard ±10% tolerances. Available with ±5.0% tolerance by adding suffix "A" to type number.

Standard cathode-to-case polarity.

For new designs and for industry preferred replacement devices, see MZ92-8.8A series.

MAXIMUM RATINGS

Junction and Storage Temperature Range: -65 to +175°C (Derate 1 mW/°C above 25°C).

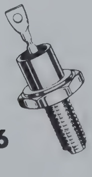
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Type	Nominal Voltage V_Z @ $I_{ZT} = 200\ \mu A$ volts	Max Reverse Current $T_A = 25°C$ I_R @ V_R μA	Max Reverse Current $T_A = 100°C$ I_A @ V_R μA	Test Voltage V_R volts
1N1313	8.75	0.5	5	6.8
1N1314	10.50	0.5	5	8.2
1N1315	12.75	0.5	5	10
1N1316	15.75	0.5	5	12
1N1317	19.00	0.5	5	15

Type	Nominal Voltage V_Z @ $I_{ZT} = 200\ \mu A$ volts	Max Reverse Current $T_A = 25°C$ I_R @ V_R μA	Max Reverse Current $T_A = 100°C$ I_A @ V_R μA	Test Voltage V_R volts
1N1318	23.50	0.1	10	18
1N1319	28.50	0.1	10	22
1N1320	34.50	0.1	10	27
1N1321	41.00	0.1	10	33
1N1322	48.50	0.1	10	39

Type	Nominal Voltage V_Z @ $I_{ZT} = 200\ \mu A$ volts	Max Reverse Current $T_A = 25°C$ I_R @ V_R μA	Max Reverse Current $T_A = 100°C$ I_A @ V_R μA	Test Voltage V_R volts
1N1323	58.00	0.1	10	47
1N1324	71.00	1.0	50	56
1N1325	87.50	1.0	50	68
1N1326	105.0	1.0	50	82
1N1327	127.5	1.0	50	100

1N1351 thru 1N1375



CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N1507 thru 1N1517

CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1.0-watt, 1N4728 series.

1N1518 thru 1N1528

CASE 52
(DO-13)

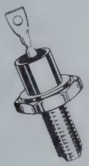
Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

1N1530, A

For Specifications, See 1N429 Data.

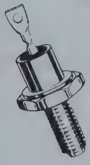
1N1588 thru 1N1598

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.



CASE 56
(DO-4)

1N1599 thru 1N1609



Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

CASE 56
(DO-4)

HIGH VOLTAGE SILICON RECTIFIERS MOLDED ASSEMBLIES

1N1730 thru 1N1734
1N2382 thru 1N2385

CASE 41

Standard single-phase, half-wave, high-voltage silicon rectifier assemblies.

MAXIMUM RATINGS (covering all devices in the table below)

Max. DC Reverse Current @ Rated Peak Reverse Voltage 25°C	10 μA
100°C	100 μA
Max. Surge Current (8 ms)	2.5A
Operating Temperature	-55°C to +150°C

ELECTRICAL CHARACTERISTICS

Rectifier Types	V_{RM} (rep)	Avg. Rectified Fwd. Current – mA		Max. RMS Input Voltage	Max. DC Fwd. Voltage @ 100mA @ 25°C	Case Dimensions		Lead Dimensions	
		@25°C	@100°C			L	Dia.	L	Dia.
1N1730	1000	200	100	700	5	.5	.375	1.250	.030
1N1731	1500	200	100	1050	5	.5	.375	1.250	.030
1N1732	2000	200	100	1400	9	1.0	.375	1.250	.030
1N1733	3000	150	75	2100	12	1.0	.375	1.250	.030
1N1734	5000	100	50	3500	18	1.0	.5	1.250	.030
1N2382	4000	150	75	2800	18	1.5	.5	1.250	.030
1N2383	6000	100	50	4200	27	1.5	.5	1.250	.030
1N2384	8000	70	35	5600	27	1.5	.5	1.250	.030
1N2385	10000	70	35	7000	39	2.0	.5	1.250	.030

1N1735 thru 1N1742 (REFERENCE DIODES)
1N1736A thru 1N1742A

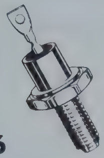
For Specifications, See 1N429 Data.

1N1765 thru 1N1802 (ZENER DIODES)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

CASE 52
(DO-13)

1N1803 thru 1N1836 (ZENER DIODES)

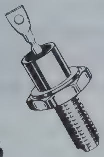


CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series, and 1N2970 series.

1N1816 thru 1N1836 are available as clipper devices. To order, add suffix "C" for ±10%, suffix "CA" for ±5%.

1N2008 thru 1N2012 (ZENER DIODES)



CASE 56
(DO-4)

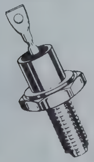
Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N2032 thru 1N2040 (ZENER DIODES)

CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

1N2041 thru 1N2049 (ZENER DIODES)



CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

1N2163 thru 1N2171 (SILICON)

1N2163A thru 1N2171A

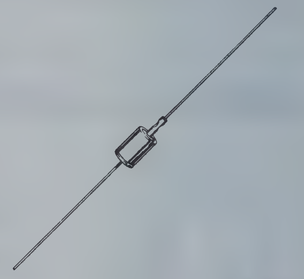
1N3580, A, B thru 1N3583, A, B

TEMPERATURE-COMPENSATED ZENER REFERENCE DIODES

Highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. Construction consists of welded hermetically sealed metal and glass case.

- Low Dynamic Impedance
- Choice of Three Temperature Ranges
- "Box Method" Specifications Guarantee Maximum Voltage Deviation.

TEMPERATURE-COMPENSATED SILICON ZENER REFERENCE DIODES



Temperature compensated reference diodes are made by taking advantage of the differing thermal characteristics of forward and reverse biased silicon PN junctions. A forward biased junction has a negative temperature coefficient of approximately 2.0 millivolts/°C. Reverse biased junctions above 5.0 volts have a positive temperature coefficient and therefore it is possible by judicious selection of combinations of forward and reverse biased junctions to obtain a device that shows a very low temperature coefficient due to cancellation. Because of the differing impedance versus temperature characteristics of the junctions involved, optimum temperature stability is obtained by operating in the zener current range at which the temperature coefficient is a minimum.

MAXIMUM RATINGS

Junction Temperature: -55 to +200°C

Storage Temperature: -65 to +200°C

DC Power Dissipation: 750 mW @ $T_A = 25°C$

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, welded metal glass

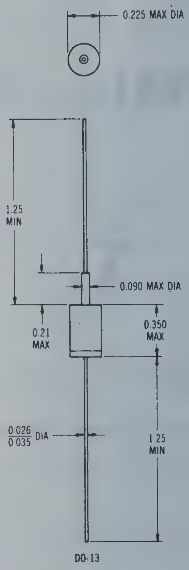
DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode to case

WEIGHT: 1.5 Grams (approx)

MOUNTING POSITION: Any



CASE 52
(DO-13)

1N2163 thru 1N2171, 1N2163A thru 1N2171A, 1N3580, A, B thru 1N3583, A, B (continued)

ELECTRICAL CHARACTERISTICS

V_Z = 9.4 Volts ± 0.4 V (± 0.2 V Suffix "A") @ (I_{ZT} = 10 mA)

Type Number	Max Voltage Change (Note 1) ΔV_Z (Volts)	Test Temperatures °C	Temperature Coefficient (Note 1) %/°C	Max Dynamic Impedance (Note 2) Z_{ZT} (Ohms)
1N2163,A	0.033	0, +25, +70	0.005	15
1N2164,A	0.086	-55, 0, +25, +75, +125	0.005	
1N2165,A	0.115	-55, 0, +25, +75, +125, +185	0.005	
1N2166,A	0.007	0, +25, +70	0.001	15
1N2167,A	0.017	-55, 0, +25, +75, +125	0.001	
1N2168,A	0.023	-55, 0, +25, +75, +125, +185	0.001	
1N2169,A	0.004	0, +25, +70	0.0005	15
1N2170,A	0.009	-55, 0, +25, +75, +125	0.0005	
1N2171,A	0.012	-55, 0, +25, +75, +125, +185	0.0005	

NOTE 1:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the maximum ΔV_Z given.

This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability — by means of temperature coefficient — accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

ELECTRICAL CHARACTERISTICS

V_Z = 11.7 Volts ± 5.0% (I_{ZT} = 7.5 mA)

Type Number	Max Voltage Change (Note 1) ΔV_Z (Volts)	Test Temperatures °C	Temperature Coefficient (Note 1) %/°C	Max Dynamic Impedance (Note 2) Z_{ZT} (Ohms)
1N3580 1N3581 1N3582 1N3583	0.088 0.044 0.018 0.009	0, +25, +75	0.01 0.005 0.002 0.001	25
1N3580A 1N3581A 1N3582A 1N3583A	0.181 0.090 0.036 0.018	-55, 0, +25, +75, +100	0.01 0.005 0.002 0.001	25
1N3580B 1N3581B 1N3582B 1N3583B	0.239 0.120 0.048 0.024	-55, 0, +25 +75, +100, +150	0.01 0.005 0.002 0.001	25

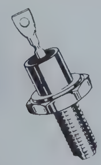
NOTE 2:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

1N2382 thru 1N2385

For Specifications, See 1N1730 Data.

1N2498 thru 1N2500



CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N2609 thru 1N2617

Obsolete, discontinued types, replace with devices from the 1N4001 series.

1N2620, A, B (SILICON)
thru
1N2624, A, B

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. Construction consists of welded hermetically sealed metal and glass case.

CASE 52
(DO-13)

MAXIMUM RATINGS

Junction Temperature: –55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 750 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, welded metal and glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode to case

WEIGHT: 1.5 Grams (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No.	Maximum Voltage Change ΔV_Z (Volts) (Note 1)	**Ambient Test Temperature °C ±1°C**	Temperature Coefficient %/°C (Note 1)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 2)
V_Z = 9.3 V ±5.0%* @ I_{ZT} = 10 mA				
1N2620	0.070	0, +25, +75	0.01	15
1N2621	0.035		0.005	
1N2622	0.014		0.002	
1N2623	0.007		0.001	
1N2624	0.003		0.0005	
1N2620A	0.144	-55, 0, +25, +75, +100	0.01	15
1N2621A	0.072		0.005	
1N2622A	0.029		0.002	
1N2623A	0.014		0.001	
1N2624A	0.007		0.0005	
1N2620B	0.191	-55, 0, +25, +75, +100, +150	0.01	15
1N2621B	0.095		0.005	
1N2622B	0.038		0.002	
1N2623B	0.019		0.001	
1N2624B	0.010		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 75 to 200 pF @ 90% of V_Z

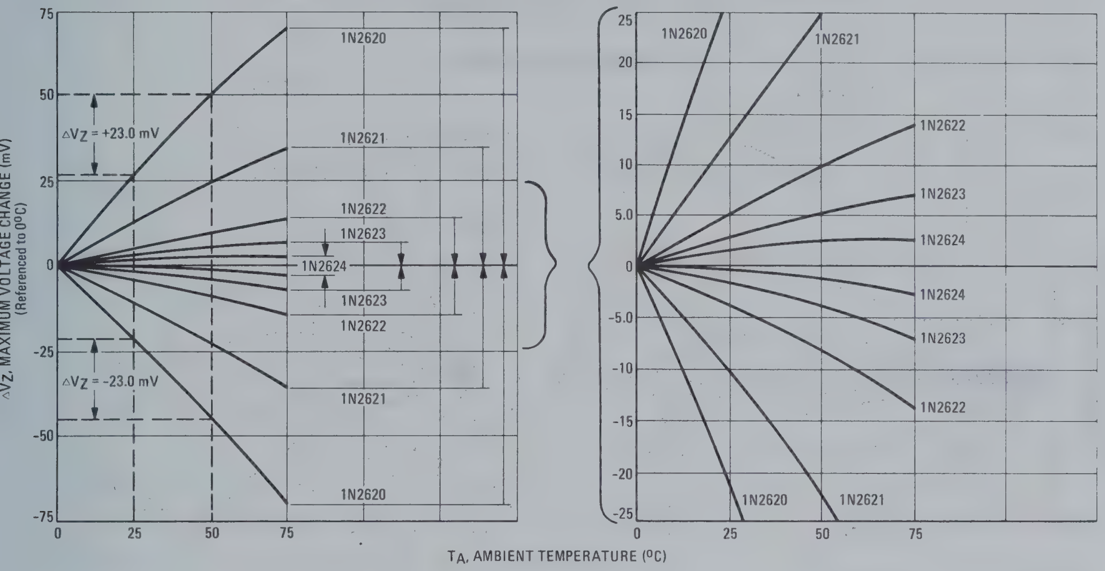
FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 10 mA ±0.01 mA) (See Note 3)

1N2620 thru 1N2624

FIGURE 1a FIGURE 1b

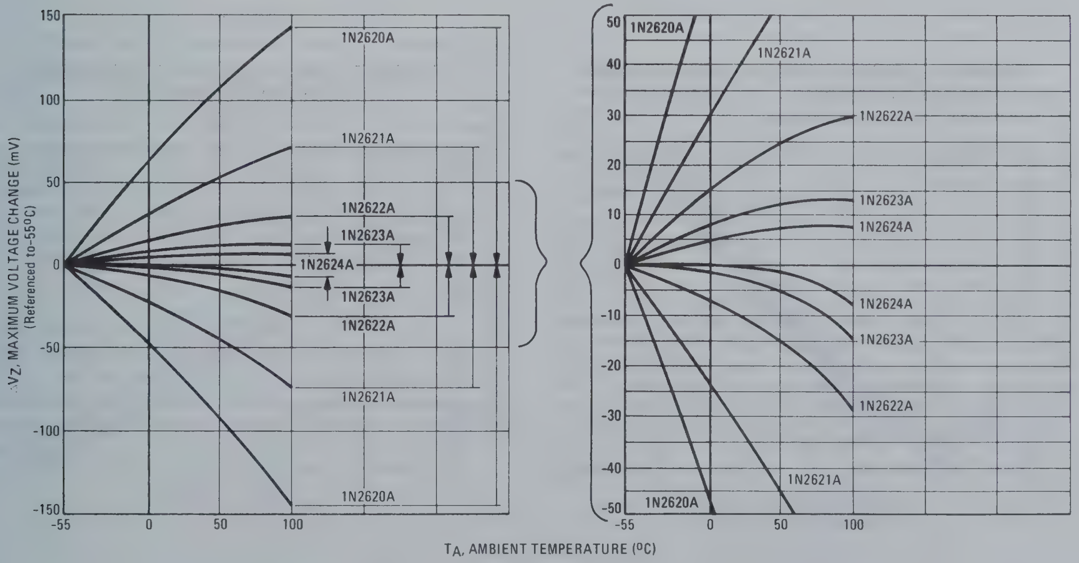


MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 10 mA ±0.01 mA) (See Note 3)

1N2620A thru 1N2624A

FIGURE 2a FIGURE 2b



MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 10 mA ±0.01 mA) (See Note 4)

1N2620B thru 1N2624B

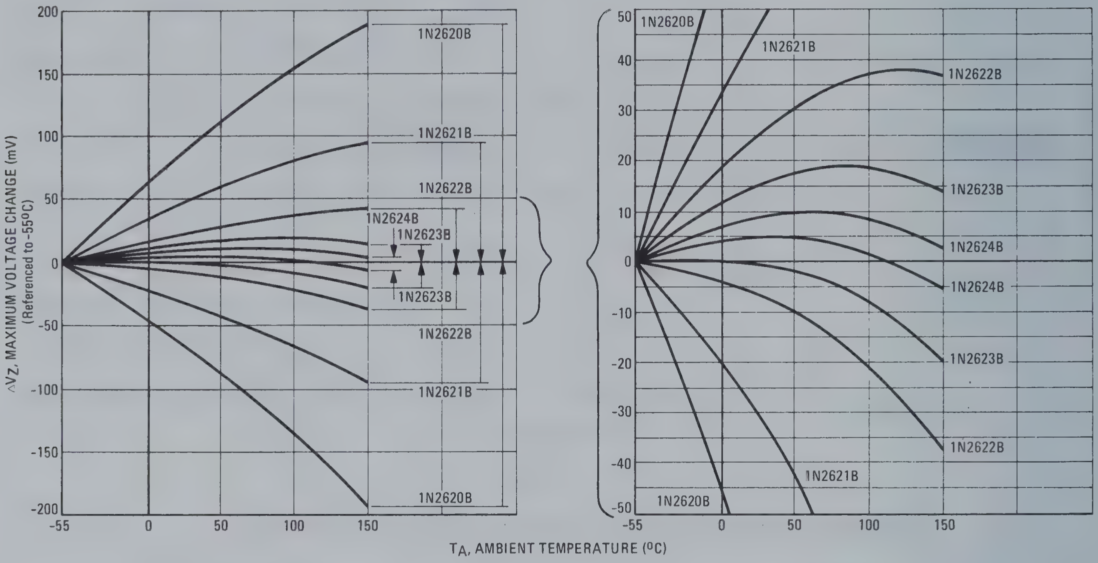


FIGURE 3a

FIGURE 3b

FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)

(See Note 4)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

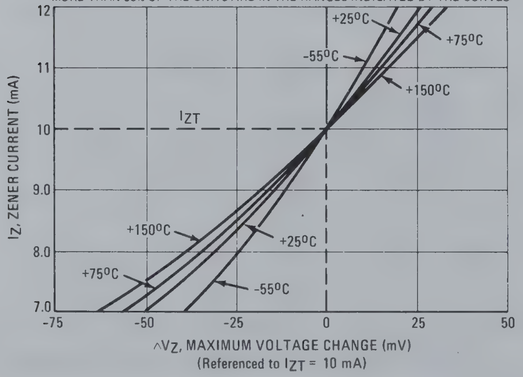


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 2)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

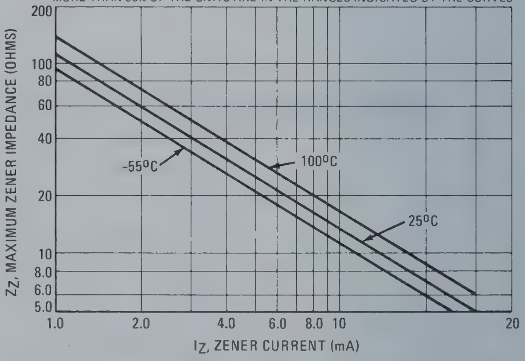
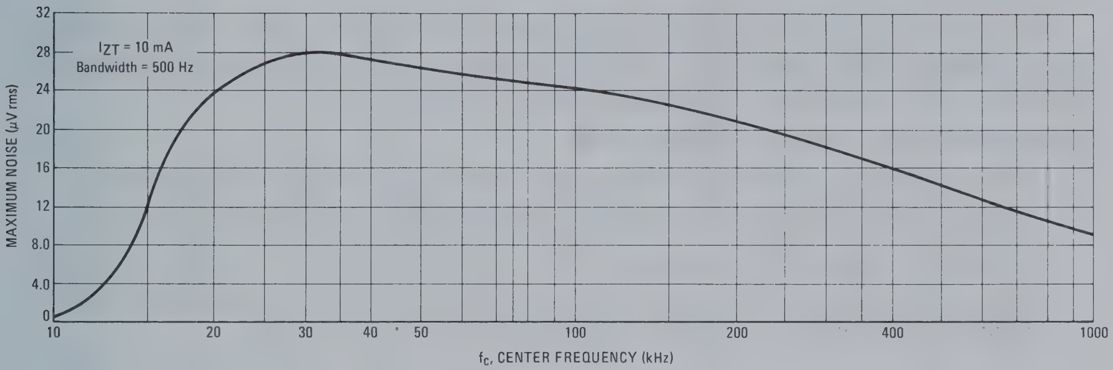


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 2:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 3:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +23 mV or −23 mV for 1N2620, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 4:

The maximum voltage change, ΔV_Z, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 4 to the ΔV_Z in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

1N2804 thru 1N2846 (ZENER DIODES)

6.8V thru 200V (Case 54)

1N4557 thru 1N4564

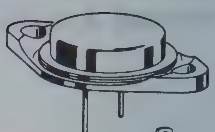
3.9V thru 7.5V (Case 54)

1N4549 thru 1N4556

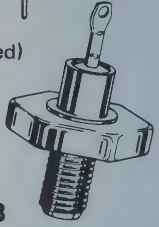
3.9V thru 7.5V (Case 58)

1N3305 thru 1N3350

6.8V thru 200V (Case 58)



CASE 54
(TO-3 Modified)



CASE 58
(stud package)

Units are available with anode-to-case and cathode-to-case connections (standard and reverse polarity). For reverse polarity, add suffix "R" to type number.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 50 Watts. (Derate 0.5 W/°C above 75°C).

TOLERANCE DESIGNATION

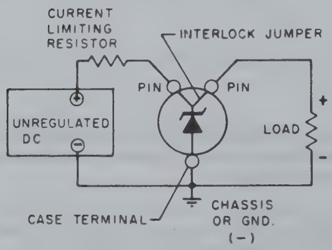
The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units. (2% and 1% tolerance also available. *(See Selector Guide for details)*

CASE 54 APPLICATIONS INFORMATION

If these units are used with a socket, the unregulated line should be connected to one pin through a suitable current limiting resistor and the load should be connected to the other pin. The load will now be disconnected from the line if the unit is removed from the socket.

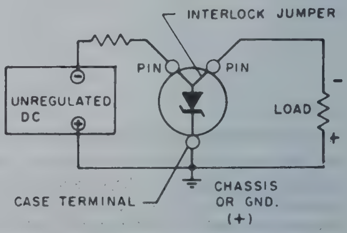
Typical circuit connections for anode-to-case and cathode-to-case polarities (standard and reverse polarities, respectively) are shown below

CIRCUIT CONNECTIONS



STANDARD POLARITY
(ANODE TO CASE)

REVERSE POLARITY
(CATHODE TO CASE)
(RED DOT ON CASE AND "R" SUFFIX ON TYPE NO)



(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES:

To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±3%, ±2%, ±1%), the Motorola type number should be used.

50	M	90	S	Z	3
Device Description	Motorola	Nominal Voltage	Stud	Zener Diode	Tolerance (±%)

Example: 50M90ZS3

(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±2.0%, ±1.0%).

Zener diodes can be obtained in sets consisting of two or more matched devices. The method for specifying such matched sets is similar to the one described in (A) for specifying units with a special voltage and/or tolerance except that two extra suffixes are added to the code number described.

These units are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set being ordered.

50	M	51	S	Z	5	B	1
Device Description	Motorola	51 Volts (each device)	Stud	Zener Diodes	Tolerance per device (±5%) (omit for ±20% units)	Code* (A-Not used)	Overall Tolerance of set (±1%)

*Code:
B – Two devices in series
C – Three devices in series
D – Four devices in series

Example: 50M51SZ5B1

(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:

50	M	20,	S	Z	Z	10
Device Description	Motorola	Nominal Voltage	Stud	Zener Diodes	Clipper	Tolerance for each of the two Zener voltages (not a matching requirement)

Example: 50M20SZZ10

1N2804 thru 1N2846 (continued)

ELECTRICAL CHARACTERISTICS

(T_C = 30°C unless otherwise specified) V_F = 1.5 V max @ 10 A on all types.

50 Watt CASE 54	50 Watt CASE 58	Nominal Zener Voltage @ I_{ZT} (V_Z) Volts	Test Current (I_{ZT}) mA	Max Zener Impedance		Max DC Zener Current 75°C Case Temp (I_{ZM}) mA	REVERSE LEAKAGE CURRENT *			Typical Zener Voltage Temp. Coeff. %/°C
				Z_{ZT} @ I_{ZT} ohms	Z_{ZK} @ I_{ZK} = 5mA ohms		I_R MAX (μA)	V_{R1}	V_{R2}	
1N4557	1N4549	3.9	3200	0.16	400	11900	150	0.5	0.5	-.025
1N4558	1N4550	4.3	2900	0.16	500	10650	150	0.5	0.5	-.025
1N4559	1N4551	4.7	2650	0.12	600	9700	100	1.0	1.0	.010
1N4560	1N4552	5.1	2450	0.12	650	8900	20	1.0	1.0	.015
1N4561	1N4553	5.6	2250	0.12	900	8100	20	1.0	1.0	.030
1N4562	1N4554	6.2	2000	0.14	1000	7300	20	2.0	2.0	.040
1N2804	1N3305	6.8	1850	0.2	70	6600	150	4.5	4.3	.040
1N4563	1N4555	6.8	1850	0.16	200	6650	10	2.0	2.0	.045
1N2805	1N3306	7.5	1700	0.3	70	5900	75	5.0	4.7	.045
1N4564	1N4556	7.5	1650	0.24	100	6050	10	3.0	3.0	.053
1N2806	1N3307	8.2	1500	0.4	70	5200	50	5.4	5.2	.048
1N2807	1N3308	9.1	1370	0.5	70	4800	25	6.1	5.7	.051
1N2808	1N3309	10	1200	0.6	80	4300	10	6.7	6.3	.055
1N2809	1N3310	11	1100	0.8	80	3900	5	8.4	8.0	.060
1N2810	1N3311	12	1000	1.0	80	3600	5	9.1	8.6	.065
1N2811	1N3312	13	960	1.1	80	3300	5	9.9	9.4	.065
1N2812	1N3313	14	890	1.2	80	3000	5	10.6	10.1	.070
1N2813	1N3314	15	830	1.4	80	2800	5	11.4	10.8	.070
1N2814	1N3315	16	780	1.6	80	2650	5	12.2	11.5	.070
1N2815	1N3316	17	740	1.8	80	2500	5	13.0	12.2	.075
1N2816	1N3317	18	700	2.0	80	2300	5	13.7	13.0	.075
1N2817	1N3318	19	660	2.2	80	2200	5	14.4	13.7	.075
1N2818	1N3319	20	630	2.4	80	2100	5	15.2	14.4	.075
1N2819	1N3320	22	570	2.5	80	1900	5	16.7	15.8	.080
1N2820	1N3321	24	520	2.6	80	1750	5	18.2	17.3	.080
1N2821	1N3322	25	500	2.7	90	1550	5	19.0	18.0	.080
1N2822	1N3323	27	460	2.8	90	1500	5	20.6	19.4	.085
1N2823	1N3324	30	420	3.0	90	1400	5	22.8	21.6	.085
1N2824	1N3325	33	380	3.2	90	1300	5	25.1	23.8	.085
1N2825	1N3326	36	350	3.5	90	1150	5	27.4	25.9	.085
1N2826	1N3327	39	320	4.0	90	1050	5	29.7	28.1	.090
1N2827	1N3328	43	290	4.5	90	975	5	32.7	31.0	.090
1N2828	1N3329	45	280	4.5	100	930	5	34.2	32.4	.090
1N2829	1N3330	47	270	5.0	100	880	5	35.8	33.8	.090
1N2830	1N3331	50	250	5.0	100	830	5	38.0	36.0	.090
1N2831	1N3332	51	245	5.2	100	810	5	38.8	36.7	.090
-	1N3333	52	240	5.5	100	790	5	39.5	37.4	.090
1N2832	1N3334	56	220	6	110	740	5	42.6	40.3	.090
1N2833	1N3335	62	200	7	120	660	5	47.1	44.6	.090
1N2834	1N3336	68	180	8	140	600	5	51.7	49.0	.090
1N2835	1N3337	75	170	9	150	540	5	56.0	54.0	.090
1N2836	1N3338	82	150	11	160	490	5	62.2	59.0	.090
1N2837	1N3339	91	140	15	180	420	5	69.2	65.5	.090
1N2838	1N3340	100	120	20	200	400	5	76.0	72.0	.090
1N2839	1N3341	105	120	25	210	380	5	79.8	75.6	.095
1N2840	1N3342	110	110	30	220	365	5	83.6	79.2	.095
1N2841	1N3343	120	100	40	240	335	5	91.2	86.4	.095
1N2842	1N3344	130	95	50	275	310	5	98.8	93.6	.095
-	1N3345	140	90	60	325	290	5	106.4	100.8	.095
1N2843	1N3346	150	85	75	400	270	5	114.0	108.0	.095
1N2844	1N3347	160	80	80	450	250	5	121.6	115.2	.095
-	1N3348	175	70	85	500	230	5	133.0	126.0	.095
1N2845	1N3349	180	68	90	525	220	5	136.8	129.6	.095
1N2846	1N3350	200	65	100	600	200	5	152.0	144.0	.100

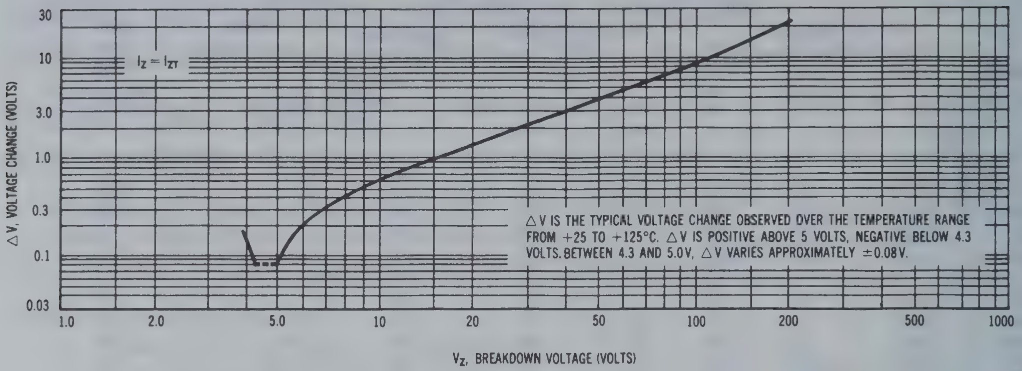
SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

*V_{R1} — Test Voltage for 5% Tolerance Device

V_{R2} — Test Voltage for 10% Tolerance Device

No Leakage Specified as 20% Tolerance Device

FIGURE 1 — TEMPERATURE CHARACTERISTICS



ΔV IS THE TYPICAL VOLTAGE CHANGE OBSERVED OVER THE TEMPERATURE RANGE FROM +25 TO +125°C. ΔV IS POSITIVE ABOVE 5 VOLTS, NEGATIVE BELOW 4.3 VOLTS. BETWEEN 4.3 AND 5.0V, ΔV VARIES APPROXIMATELY ±0.08V.

FIGURE 2 — POWER-TEMPERATURE DERATING CURVE

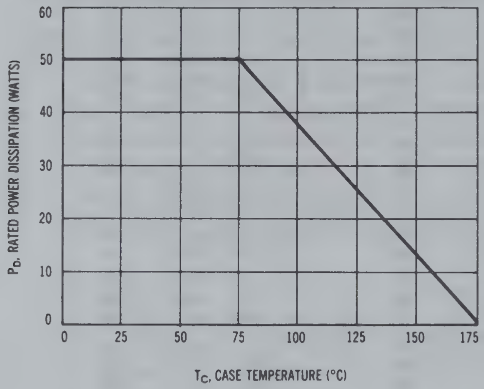
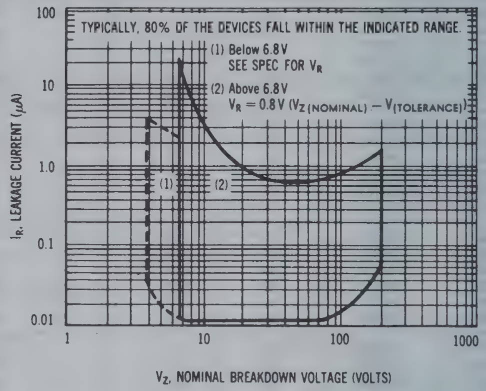


FIGURE 3 — LEAKAGE CURRENT

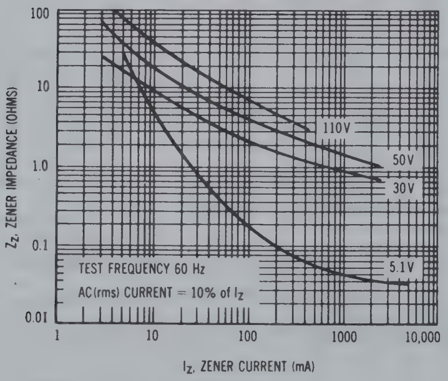


TYPICALLY, 80% OF THE DEVICES FALL WITHIN THE INDICATED RANGE.

(1) Below 6.8V SEE SPEC FOR V_R

(2) Above 6.8V $V_R = 0.8\,V\,(V_{Z\,(NOMINAL)} - V_{(TOLERANCE)})$

FIGURE 4 — ZENER IMPEDANCE versus ZENER CURRENT



TEST FREQUENCY 60 Hz

AC(rms) CURRENT = 10% of I_Z

1N2970 thru 1N3015 (ZENER DIODES)

CASE 56
(DO-4)

Diffused-junction zener diodes for both military and high-reliability industrial applications. Available with anode-to-case and cathode-to-case connections (standard and reverse polarity), i. e., 1N2970 and 1N2970R. Supplied with mounting hardware.

The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units. (2% and 1% tolerance also available.)

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 10 Watts. (Derate 83.3 mW/°C above 55°C).

ELECTRICAL CHARACTERISTICS

(T_C = 25°C unless otherwise noted) $V_F = 1.5$ V max @ $I_F = 2$ amp on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance			Max DC Zener Current I_{ZM} mA	Max. Reverse Current *		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R Max (μA)	V_{R1}	V_{R2}
1N2970	6.8	370	1.2	500	1.0	1,320	150	5.2	4.9
1N2971	7.5	335	1.3	250	1.0	1,180	75	5.7	5.4
1N2972	8.2	305	1.5	250	1.0	1,040	50	6.2	5.9
1N2973	9.1	275	2.0	250	1.0	960	25	6.9	6.6
1N2974	10	250	3	250	1.0	860	10	7.6	7.2
1N2975	11	230	3	250	1.0	780	5	8.4	8.0
1N2976	12	210	3	250	1.0	720	5	9.1	8.6
1N2977	13	190	3	250	1.0	660	5	9.9	9.4
1N2978	14	180	3	250	1.0	600	5	10.6	10.1
1N2979	15	170	3	250	1.0	560	5	11.4	10.8
1N2980	16	155	4	250	1.0	530	5	12.2	11.5
1N2982	18	140	4	250	1.0	460	5	13.7	13.0
1N2983	19	130	4	250	1.0	440	5	14.4	13.7
1N2984	20	125	4	250	1.0	420	5	15.2	14.4
1N2985	22	115	5	250	1.0	380	5	16.7	15.8
1N2986	24	105	5	250	1.0	350	5	18.2	17.3
1N2988	27	95	7	250	1.0	300	5	20.6	19.4
1N2989	30	85	8	300	1.0	280	5	22.8	21.6
1N2990	33	75	9	300	1.0	260	5	25.1	23.8
1N2991	36	70	10	300	1.0	230	5	27.4	25.9

*V_{R1} — Test Voltage for 5% Tolerance Device. V_{R2} — Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES:

To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±3%, ±2%, ±1%), the Motorola type number should be used.

10 — Device Description
M — Motorola
90 — Nominal Voltage
Z — Zener Diode
3 — Tolerance (±%)

Example: 10M90Z3

(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±2.0%, ±1.0%).

Zener diodes can be obtained in sets consisting of two or more matched devices. The method for specifying such matched sets is similar to the one described in (A) for specifying units with a special voltage and/or tolerance except that two extra suffixes are added to the code number described.

These units are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set being ordered.

10 — Device Description
M — Motorola
51 — 51 Volts (each device)
Z — Zener Diodes
5 — Tolerance per device (±5%) (omit for ±20% units)
B — Code*
1 — Overall Tolerance of set (±1%)

*Code: (A-Not used)
B – Two devices in series
C – Three devices in series
D – Four devices in series

Example: 10M515B1

(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:

10 — Device Description
M — Motorola
20, — Nominal Voltage
Z — Zener Diodes
Z — Clipper
10 — Tolerance for each of the two Zener voltages (not a matching requirement)

Example: 10M20ZZ10

1N2970 thru 1N3015 (continued)

ELECTRICAL CHARACTERISTICS

(T_C = 25°C unless otherwise noted) V_F = 1.5 V max @ I_F = 2 amp on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance			Max DC Zener Current I_{ZM} mA	Max. Reverse Current *		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R Max (μA)	V_{R1}	V_{R2}
1N2992	39	65	11	300	1.0	210	5	29.7	28.1
1N2993	43	60	12	400	1.0	195	5	32.7	31.0
1N2995	47	55	14	400	1.0	175	5	35.8	33.8
1N2996	50	50	15	500	1.0	165	5	38.0	36.0
1N2997	51	50	15	500	1.0	163	5	38.8	36.7
1N2998	52	50	15	500	1.0	160	5	39.5	37.4
1N2999	56	45	16	500	1.0	150	5	42.6	40.3
1N3000	62	40	17	600	1.0	130	5	47.1	44.6
1N3001	68	37	18	600	1.0	120	5	51.7	49.0
1N3002	75	33	22	600	1.0	110	5	56.0	54.0
1N3003	82	30	25	700	1.0	100	5	62.2	59.0
1N3004	91	28	35	800	1.0	85	5	69.2	65.5
1N3005	100	25	40	900	1.0	80	5	76.0	72.0
1N3006	105	25	45	1,000	1.0	75	5	79.8	75.6
1N3007	110	23	55	1,100	1.0	72	5	83.6	79.2
1N3008	120	20	75	1,200	1.0	67	5	91.2	86.4
1N3009	130	19	100	1,300	1.0	62	5	98.8	93.6
1N3010	140	18	125	1,400	1.0	58	5	106.4	100.8
1N3011	150	17	175	1,500	1.0	54	5	114.0	108.0
1N3012	160	16	200	1,600	1.0	50	5	121.6	115.2
1N3014	180	14	260	1,850	1.0	45	5	136.8	129.6
1N3015	200	12	300	2,000	1.0	40	5	152.0	144.0

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

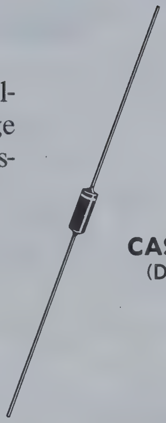
*V_{R1} – Test Voltage for 5% Tolerance Device. V_{R2} – Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

1N3016 thru 1N3051

For Specifications, See 1N3821 Data.

1N3154, A (SILICON)
thru
1N3157, A

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.



CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 500 mW @ $T_A = 25°C$

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	**Ambient Test Temperature °C ±1°C**	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 8.4 V ±5.0%* @ I_{ZT} = 10 mA				
1N3154	0.130	-55, 0, +25, +75, +100	0.01	15
1N3155	0.065		0.005	
1N3156	0.026		0.002	
1N3157	0.013		0.001	
1N3154A	0.172	-55, 0, +25, +75, +100, +150	0.01	15
1N3155A	0.086		0.005	
1N3156A	0.034		0.002	
1N3157A	0.017		0.001	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 20 to 180 pF @ 90% of V_Z

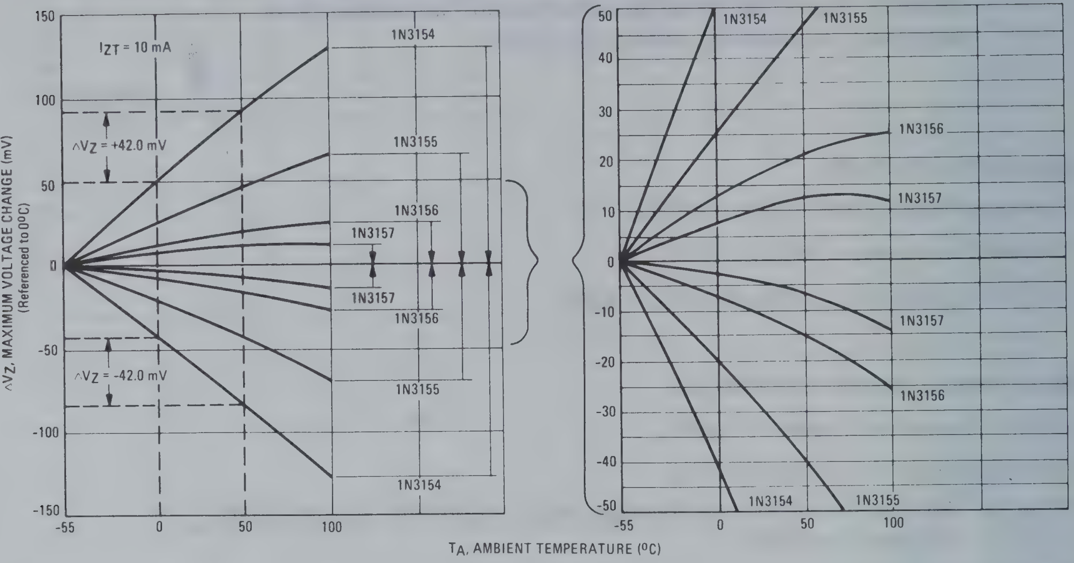
FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} = 10 mA ±0.01 mA) (See Note 4)

1N3154 thru 1N3157

FIGURE 1a FIGURE 1b

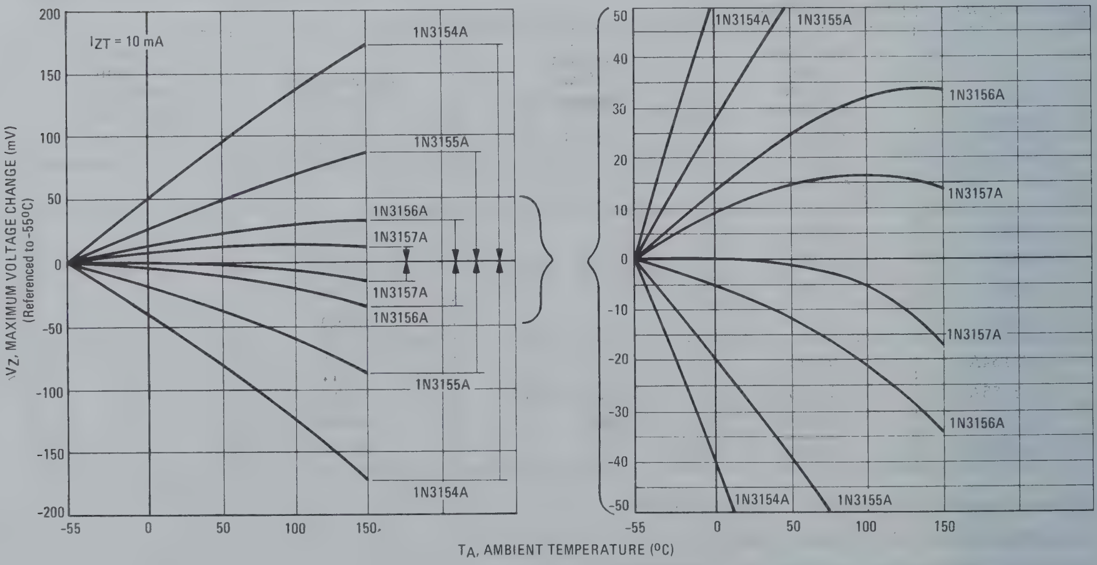


MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} - 10 mA ±0.01 mA) (See Note 4)

1N3154A thru 1N3157A

FIGURE 2a FIGURE 2b



1N3154, A thru 1N3157, A (continued)

FIGURE 3 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)
(See Note 5)

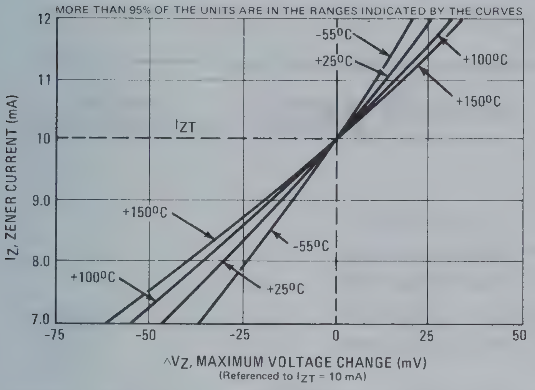


FIGURE 4 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT
(See Note 3)

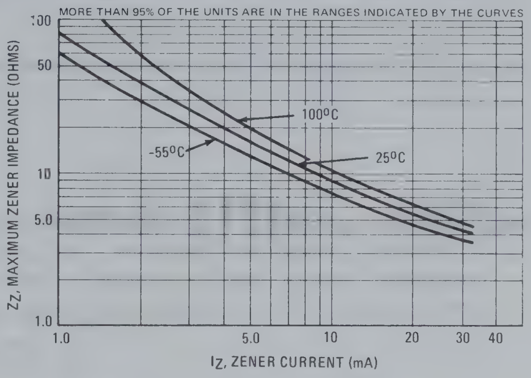
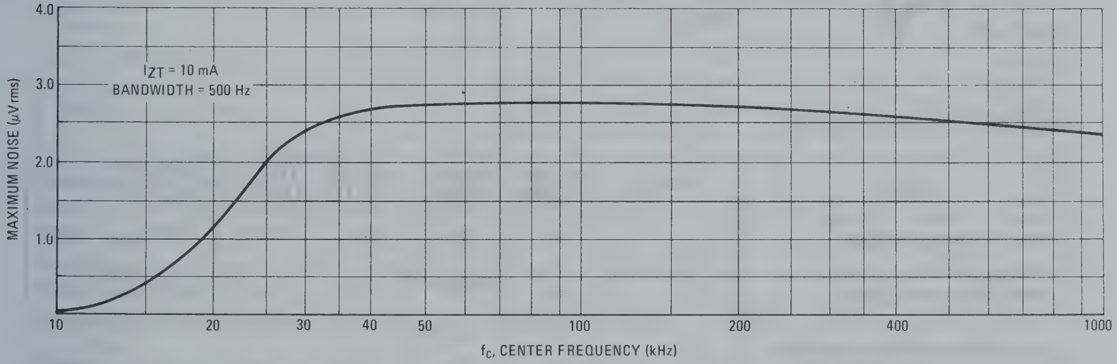


FIGURE 5 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N3154 thru 1N3157 are available to MIL-S-19500/158

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}.

Curves showing the variation of zener impedance with zener current for each series are given in Figure 4. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from 0 to +50°C will cause a voltage change no greater than +42 mV or -42 mV for 1N3154, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution,. expanded views of the shaded areas in Figures 1a and 2a are shown in Figures 1b and 2b respectively.

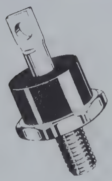
NOTE 5:

The maximum voltage change, ΔV_Z, in Figure 3 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 3 to the ΔV_Z in Figure 1 or 2 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 3 on Figure 1 or 2.

1N3189 thru 1N3191

Obsolete, discontinued types, replace with devices from the 1N4001 series.

1N3208 thru 1N3212 (SILICON)



CASE 42
(DO-5)

Medium-current silicon rectifiers. Cathode connected to case, but reverse polarity (anode-to-case connection) also available by adding suffix "R" to type number, e.g. 1N3208R. Supplied with mounting hardware.

MAXIMUM RATINGS

Rating	Symbol	1N3208 1N3208R	1N3209 1N3209R	1N3210 1N3210R	1N3211 1N3211R	1N3212 1N3212R	Unit
D C Blocking Voltage	V_R	50	100	200	300	400	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	Volts
Average Half-Wave Rectified Forward Current With Resistive Load	I_O*	15	15	15	15	15	Amp
Peak One Cycle Surge Current (60 cps & 25°C Case Temp)	$I_{FM(surge)}$	250	250	250	250	250	Amp
Operating Junction Temperature	T_J	-65 to + 175					°C
Storage Temperature	T_{stg}	-65 to + 175					°C

*T_C = 150°C

ELECTRICAL CHARACTERISTICS (All Types) at 25°C Case Temp.

Characteristic	Symbol	Value	Unit
Maximum Forward Voltage at 40 Amp D-C Forward Current	V_F	1.5	Volts
Maximum Reverse Current at Rated D-C Reverse Voltage	I_R	1.0	mAdc
Typical Thermal Resistance, Junction To Case	θ_{JC}	1.7	C/W

1N3213, 1N3214

For Specifications, See 1N248B Data.

1N3282 thru 1N3286 (SILICON)

CASE 51
(DO-7)

Low-current silicon rectifiers for applications requiring extremely high reverse-voltage capability. Hermetically sealed, subminiature glass package, offering excellent stability and reliability under environmental extremes.

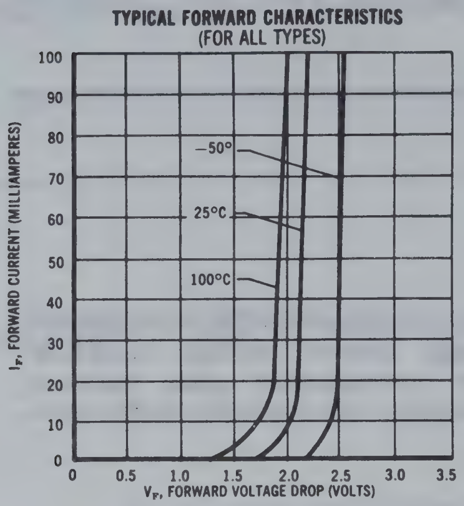
MAXIMUM RATINGS (At 60 cps Sinusoidal Input, Resistive or Inductive Load)

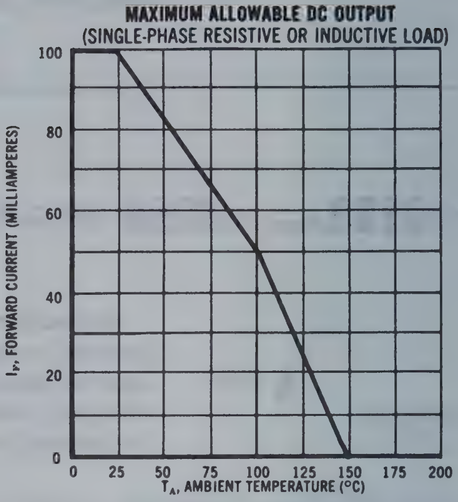
Rating	Symbol	1N3282	1N3283	1N3284	1N3285	1N3286	Unit
Peak Repetitive Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ V_R	1000	1500	2000	2500	3000	Volts
RMS Reverse Voltage	V_r	700	1050	1400	1750	2100	Volts
Average Half-Wave Rectified Forward Current (25°C Ambient) (100°C Ambient)	I_O	100 50	100 50	100 50	100 50	100 50	mA mA
Peak Surge Current (1/2-cycle, 60 Hz)	$I_{FM(surge)}$	2.5	2.5	2.5	2.5	2.5	Amp
Peak Repetitive Forward Current	$I_{FM(rep)}$	0.50	0.50	0.50	0.50	0.50	Amp
Operating and Storage Temperature Range	T_J, T_{stg}	-65 to + 150					°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Maximum Forward Voltage Drop @ 100 mA, Continuous DC (25°C)	V_F	2.5	Volts
Maximum Full-Cycle Average Forward Voltage Drop @ Rated Current (100°C)	$V_{F(AV)}$	1.2	Volts
Maximum Reverse Current @ Rated DC Voltage (25°C) (100°C)	I_R	1.0 10.0	µA
Maximum Full-Cycle Average Reverse Current @ Max Rated PIV and Current (as Half-Wave Rectifier, Resistive Load, 100°C)	$I_{R(AV)}$	10.0	µA
Typical Thermal Resistance, Junction to Ambient	θ_{JA}	400	°C/W

1N3282 thru 1N3286 (continued)

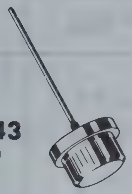




1N3305 thru 1N3350

For Specifications, see 1N2804 Data.

1N3491 thru 1N3495 (SILICON)
(MR322 thru MR328)
MR330, MR331



Medium-current silicon rectifiers – compact, highly efficient silicon rectifiers for medium-current applications.

MAXIMUM RATINGS

Rating	Symbol	1N3491 MR322	1N3492 MR323	1N3493 MR324	1N3494 MR325	1N3495 MR326	MR327	MR328	MR330	MR331	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	500	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (halfwave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	100	200	300	400	500	600	720	1000	1200	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	350	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz , see Figure 3) T_C = 130°C	I_O	25									Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions, see Figure 5)	$I_{FM(surge)}$	300 (for 1/2 cycle)									Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	375									$A_{(rms)}{}^2$ sec
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175									°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	°C/Watt

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed construction.

FINISH: All external surfaces corrosion-resistant and the terminal lead is readily solderable.

POLARITY: CATHODE TO CASE (reverse polarity units are available upon request and are designated by an "R" suffix i.e. MR327R or 1N3491R).

MOUNTING POSITIONS: Any.

ELECTRICAL CHARACTERISTICS

Characteristic and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$V_{F(AV)}$	0.6	Volts
Instantaneous Forward Voltage Drop (i_F = 100 Amps, T_J = 25°C)	V_F	1.5	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$I_{R(AV)}$		mA
1N3491/MR322		10	
1N3492/MR323		10	
1N3493/MR324		8.0	
1N3494/MR325		6.0	
1N3495/MR326		4.0	
MR327		3.0	
MR328		2.5	
MR330		2.0	
MR331		1.5	
DC Reverse Current (Rated V_R, T_C = 25°C)	I_R	1.0	mA

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

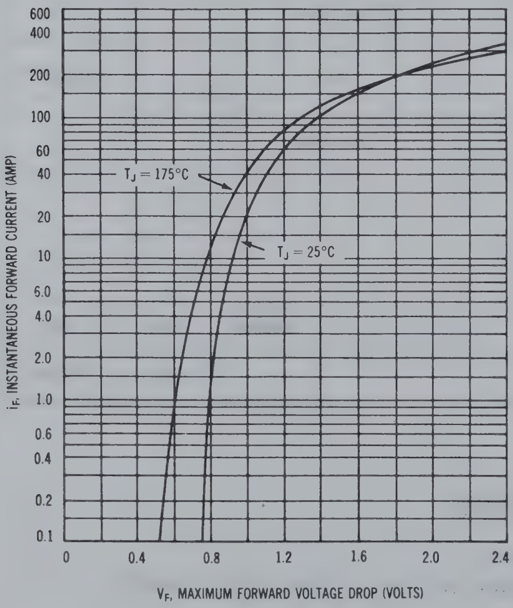
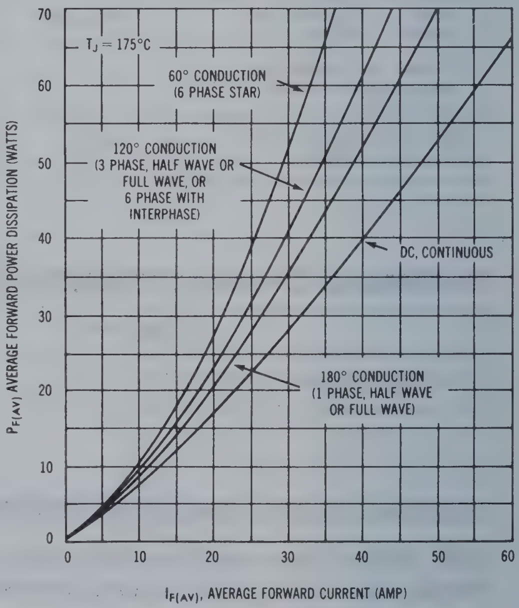


FIGURE 2 — MAXIMUM FORWARD POWER DISSIPATION



1N3491 thru 1N3495 (continued)

FIGURE 3 — MAXIMUM CURRENT RATINGS

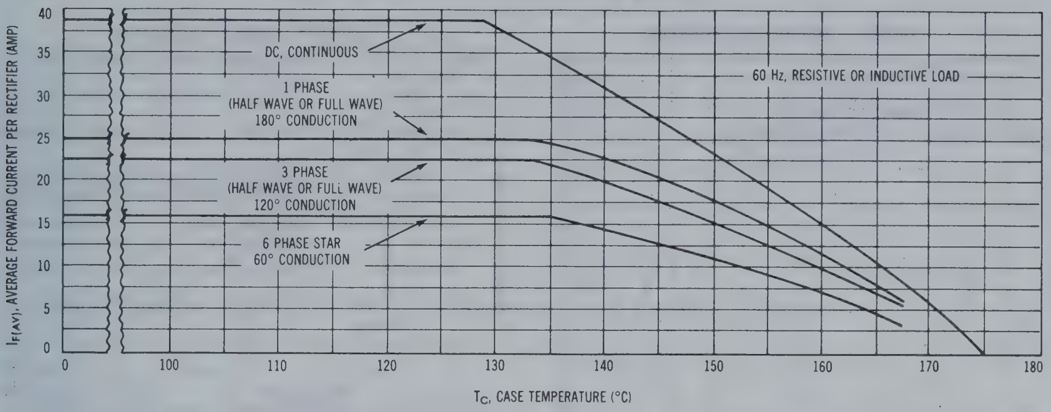


FIGURE 4 — MAXIMUM EFFECTIVE TRANSIENT THERMAL IMPEDANCE

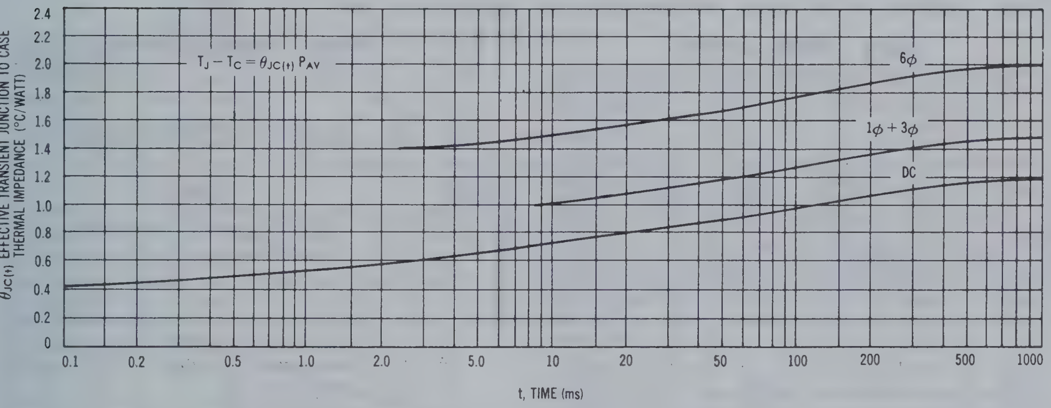
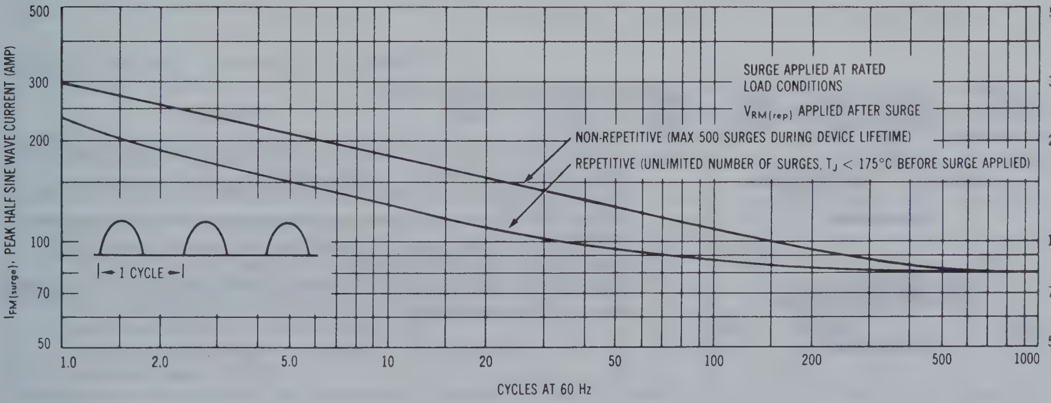


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT



TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 6 — RECTIFICATION EFFICIENCY

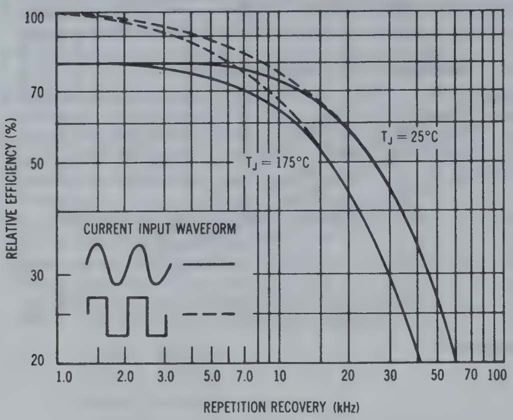


FIGURE 7 — REVERSE RECOVERY TIME

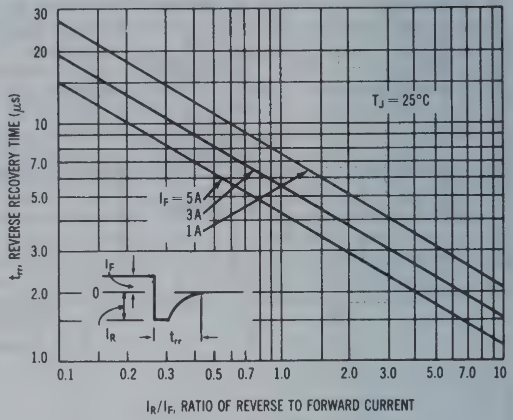


FIGURE 8 — JUNCTION CAPACITANCE

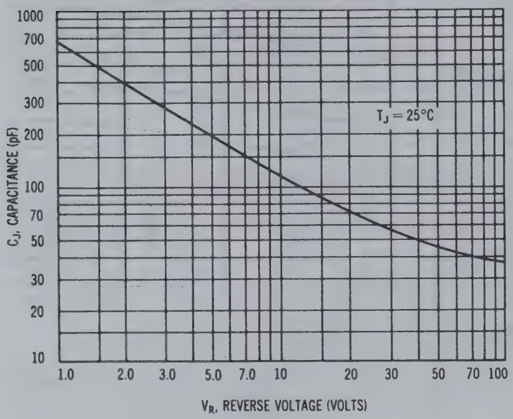
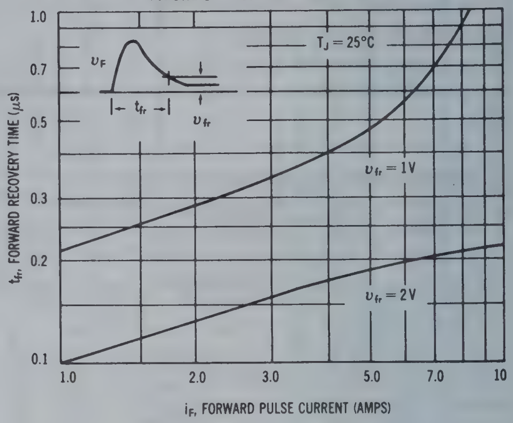
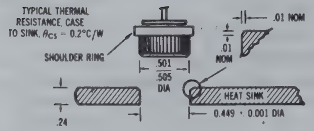
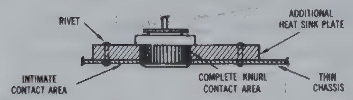


FIGURE 9 — FORWARD RECOVERY TIME




TYPICAL THERMAL RESISTANCE, CASE TO SINK, θCS = 0.2°C/W
SHOULDER RING
.501
.505
DIA
.01 NOM
.01
NOM
HEAT SINK
0.449 ± 0.001 DIA
.24

HEAT SINK MOUNTING


RIVET
ADDITIONAL HEAT SINK PLATE
INTIMATE CONTACT AREA
COMPLETE KNURL CONTACT AREA
THIN CHASSIS

THIN-CHASSIS MOUNTING

MOUNTING PROCEDURES

MR322-MR331 and 1N3491-1N3495 rectifiers are designed to be press-fitted in a heat sink in order to attain full device ratings. Recommended procedures for this type of mounting are as follows:

1. Drill a hole in the heat sink 0.499 ± .001 inch in diameter.
2. Break the hole edge as shown to prevent shearing off the knurled edge of the rectifier when it is pressed into the hole.
3. The depth and width of the break should be 0.010 inch maximum to retain maximum heat sink surface contact.
4. To prevent damage to the rectifier during press-in, the pressing force should be applied only on the shoulder ring of the rectifier case as shown in the figure.
5. The pressing force should be applied evenly about the shoulder ring to avoid tilting or canting of the rectifier case in the hole during the press-in operation. Also, the use of a light industrial lubricant will be of considerable aid.

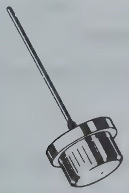
1N3580, A, B thru 1N3583, A, B

For Specifications, See 1N2163 Data.

1N3649, 1N3650

Obsolete, discontinued types, replace with devices from the MR1120 series.

1N3659 thru 1N3663 (SILICON)



CASE 43
(DO-21)

Low-cost silicon rectifiers in hermetically sealed, press-fit case, designed for operation under severe environmental conditions. Cathode connected to case, but available with reverse polarity by adding suffix "R" to type number.

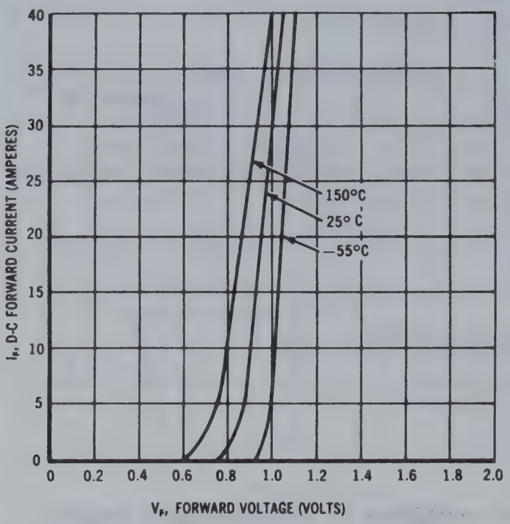
MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

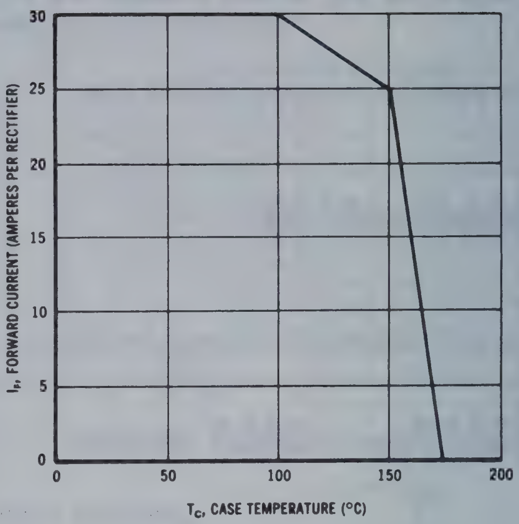
Rating	Symbol	1N3659 1N3659R	1N3660 1N3660R	1N3661 1N3661R	1N3662 1N3662R	1N3663 1N3663R	Units
Peak Repetitive Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ V_R	50	100	200	300	400	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	Volts
Average Half-Wave Rectified Forward Current with Resistive Load @ 100°C case @ 150°C case	I_O	 30 25					 Amp Amp
Peak One Cycle Surge Current (150°C case temp, 60 Hz)	$I_{FM(surge)}$	400					Amp
Operating Junction Temperature	T_J	−65 to +175					°C
Storage Temperature	T_{stg}	−65 to +200					°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	1N3659 1N3659R	1N3660 1N3660R	1N3661 1N3661R	1N3662 1N3662R	1N3663 1N3663R	Unit
Maximum Forward Voltage at 25 Amp DC Forward Current	V_F	1.2	1.2	1.2	1.2	1.2	Volts
Maximum Full Cycle Average Forward Voltage Drop @ Rated PIV and Current	$V_{F(AV)}$	0.7	0.7	0.7	0.7	0.7	Volts
Maximum Full Cycle Average Reverse Current @ Rated PIV and Current (as half-wave rectifier, resistive load, 150°C)	$I_{R(AV)}$	5.0	4.5	4.0	3.5	3.0	mA
Thermal Resistance	θ_{JC}	1.0					°C/W

1N3659 thru 1N3663 (continued)



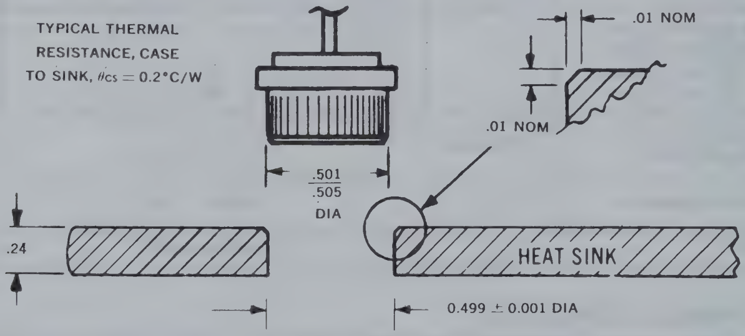


1N3659-1N3663 rectifiers are designed for press-fitted mounting in a heat sink. Recommended procedures for this type of mounting are as follows:

1. Drill a hole in the heat sink 0.499 ± .001 inch in diameter.
2. Break the hole edge as shown to prevent shearing off the knurled edge of the rectifier when it is pressed into the hole.
3. The depth of the break should be 0.010 inch maximum to retain maximum heat sink surface contact with the knurled rectifier surface.
4. Width of the break should be 0.010 inch as shown.

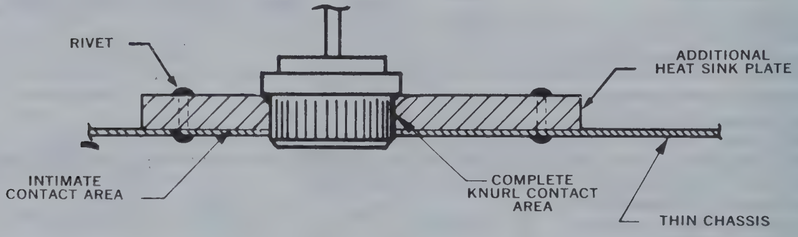
These procedures will allow proper entry of the rectifier knurled surface, provide good rectifier- heat sink surface contact, and assure reliable rectifier operation. If the break is made too deep, thereby reducing contact area for heat transfer, reliability of operation will be impaired.

These devices can be mounted in a thin chassis by inserting the rectifier through an additional heat sink plate which is mounted in intimate contact with the upper side of the chassis. This provides additional contact area for the rectifier knurled edge, as well as additional heat sink capacity.



TYPICAL THERMAL RESISTANCE, CASE TO SINK, $\theta_{CS} = 0.2°C/W$
.01 NOM
.01 NOM
.501
.505
DIA
.24
HEAT SINK
0.499 ± 0.001 DIA

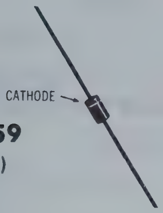
HEAT SINK MOUNTING



RIVET
ADDITIONAL HEAT SINK PLATE
INTIMATE CONTACT AREA
COMPLETE KNURL CONTACT AREA
THIN CHASSIS

THIN-CHASSIS MOUNTING

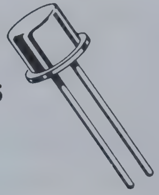
1N3675 thru 1N3703 (SILICON)



CASE 59
(DO-41)

Recommended for applications requiring an exact replacement only. For new designs and industry preferred replacement devices, see 1N4728 series.

1N3785 thru 1N3820



CASE 55

Low silhouette single-ended package for printed circuit or socket mounting. Cathode connected to case.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.

D C Power Dissipation: 1.5 Watts at 25°C Ambient. (Derate 10 mW/°C).

The type numbers shown have a standard tolerance of ±20% on the zener voltage. Standard tolerances of ±10% and ±5% on individual units are also available and are indicated by suffixing "A" for ±10% and "B" for ±5% units to the standard type number.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

$V_F = 1.5$ V max @ 300 mA

Type No.	Nominal Zener Voltage @ I_{ZT} (V_Z) Volts	Test Current (I_{ZT}) mA	Max Zener Impedance			Max DC Zener Current (I_{ZM}) mA	Reverse Leakage Current*			Typical Zener Voltage Temp. Coeff. %/°C
			Z_{ZT} @ I_{ZT} ohms	Z_{ZK} @ I_{ZK} ohms	I_{ZK} mA		I_R Max (µA)	V_{R1}	V_{R2}	
1N3785	6.8	55	2.7	700	1.0	195	150	5.2	4.9	.040
1N3786	7.5	50	3.0	700	0.5	175	75	5.7	5.4	.045
1N3787	8.2	46	3.5	700	0.5	155	50	6.2	5.9	.048
1N3788	9.1	41	4.0	700	0.5	140	25	6.9	6.6	.051
1N3789	10	37	5	700	0.25	125	10	7.6	7.2	.055
1N3790	11	34	6	700	0.25	115	5	8.4	8.0	.060
1N3791	12	31	7	700	0.25	105	5	9.1	8.6	.065
1N3792	13	29	8	700	0.25	98	5	9.9	9.4	.065
1N3793	15	25	10	700	0.25	85	5	11.4	10.8	.070
1N3794	16	23	11	700	0.25	80	5	12.2	11.5	.070
1N3795	18	21	13	750	0.25	70	5	13.7	13.0	.075
1N3796	20	19	15	750	0.25	62	5	15.2	14.4	.075
1N3797	22	17	16	750	0.25	56	5	16.7	15.8	.080
1N3798	24	16	17	750	0.25	51	5	18.2	17.3	.080
1N3799	27	14	20	750	0.25	46	5	20.6	19.4	.085
1N3800	30	12	25	1,000	0.25	41	5	22.8	21.6	.085
1N3801	33	11	30	1,000	0.25	38	5	25.1	23.8	.085
1N3802	36	10	35	1,000	0.25	35	5	27.4	25.9	.085
1N3803	39	10	40	1,000	0.25	31	5	29.7	28.1	.090
1N3804	43	9.0	45	1,500	0.25	28	5	32.7	31.0	.090
1N3805	47	8.0	55	1,500	0.25	26	5	35.8	33.8	.090
1N3806	51	7.4	65	2,000	0.25	24	5	38.8	36.6	.090
1N3807	56	6.7	75	2,000	0.25	22	5	42.6	40.3	.090
1N3808	62	6.0	85	2,000	0.25	20	5	47.1	44.6	.090
1N3809	68	5.5	95	2,000	0.25	18	5	51.7	49.0	.090
1N3810	75	5.0	110	2,000	0.25	16	5	56.0	54.0	.090
1N3811	82	4.5	130	3,000	0.25	14	5	62.0	59.0	.090
1N3812	91	4.1	150	3,000	0.25	13	5	69.2	65.5	.090
1N3813	100	3.7	200	3,000	0.25	12.0	5	76.0	72.0	.090
1N3814	110	3.4	300	4,000	0.25	11.0	5	83.6	79.2	.095
1N3815	120	3.1	350	4,500	0.25	10.5	5	91.2	86.4	.095
1N3816	130	2.9	400	5,000	0.25	9.0	5	98.8	93.6	.095
1N3817	150	2.5	700	6,000	0.25	8.0	5	114.0	108.0	.095
1N3818	160	2.3	750	6,500	0.25	8.0	5	121.8	115.0	.095
1N3819	180	2.1	800	7,000	0.25	7.0	5	137.0	130.0	.095
1N3820	200	1.9	1,000	8,000	0.25	6.0	5	152.0	144.0	.100

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} — Test Voltage for 5% Tolerance Device. V_{R2} — Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

1N3821 thru 1N3830 (SILICON)
SERIES
(1M3.3AZ10 thru 1M7.5AZ10)

1N3016 thru 1N3051
SERIES
(1M6.8Z thru 1M200Z)

Designers Data Sheet

1.0 WATT METAL SILICON ZENER DIODES

. . . a complete series of 1.0 Watt Zener Diodes with limits and operating characteristics that reflect the superior capabilities of silicon-oxide-passivated junctions. All this in an axial-lead, metal package offering protection in all common environmental conditions.

- To 100 Watts Surge Rating @ 10 ms
- Maximum Limits Guaranteed on Five Electrical Parameters
- Power Capability to MIL-S-19500 Specifications

Designer's Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
DC Power Dissipation @ T_A = 25°C Derate above 25°C (See Figure 1)	P_D	1.0 6.67	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C
Lead Temperature 230°C at a distance not less than 1/16" from the case for 10 seconds.			

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed metal and glass.

DIMENSIONS: See outline drawing.

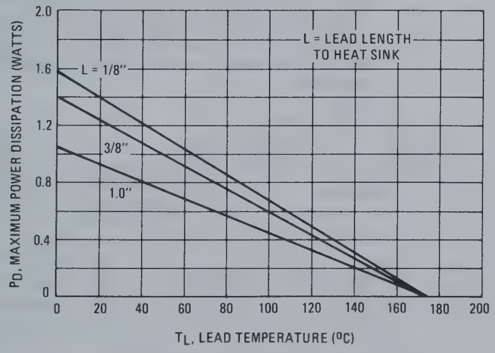
FINISH: All external surfaces are corrosion-resistant and leads are readily solderable and weldable.

POLARITY: Cathode connected to the case. When operated in zener mode, cathode will be positive with respect to anode.

WEIGHT: 1.4 Grams (approx)

MOUNTING POSITION: Any

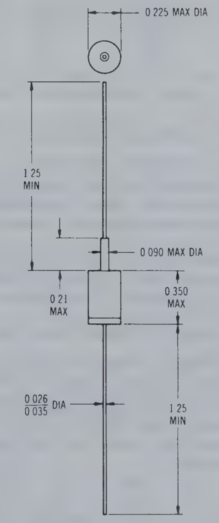
FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



*Indicates JEDEC Registered Data.

1.0 WATT
ZENER REGULATOR DIODES

3.3—200 VOLTS



All JEDEC dimensions and notes apply

CASE 52
DO-13

ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)
$V_F = 1.5$ V max @ $I_F = 200$ mA for all types

JEDEC Type No. (Flangeless) (Note 1 & 2)	*Nominal Zener Voltage V_Z @ I_{ZT} Volts (Note 3)	*Test Current I_{ZT} mA	*Max Zener Impedance (Note 4)			Max Reverse Current (Note 5)			*Max DC Zener Current I_{ZM} mA (Note 6)
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA	I_R Max (µA)	V_{R1} 5%	V_{R2} 10%	
1N3821	3.3	76	10	400	1.0	*100	*1.0	1.0	276
1N3822	3.6	69	10	400	1.0	*100	*1.0	1.0	252
1N3823	3.9	64	9.0	400	1.0	*50	*1.0	1.0	238
1N3824	4.3	58	9.0	400	1.0	*10	*1.0	1.0	213
1N3825	4.7	53	8.0	500	1.0	*10	*1.0	1.0	194
1N3826	5.1	49	7.0	550	1.0	*10	*1.0	1.0	178
1N3827	5.6	45	5.0	600	1.0	*10	*2.0	2.0	162
1N3828	6.2	41	2.0	700	1.0	*10	*3.0	3.0	146
1N3829	6.8	37	1.5	500	1.0	*10	*3.0	3.0	133
1N3830	7.5	34	1.5	250	1.0	*10	*3.0	3.0	121
1N3016	6.8	37	3.5	700	1.0	10	5.2	4.9	140
1N3017	7.5	34	4.0	700	0.5	10	5.7	5.4	125
1N3018	8.2	31	4.5	700	0.5	10	6.2	5.9	115
1N3019	9.1	28	5.0	700	0.5	7.5	6.9	6.6	105
1N3020	10	25	7.0	700	0.25	5.0	7.6	7.2	95
1N3021	11	23	8.0	700	0.25	5.0	8.4	8.0	85
1N3022	12	21	9.0	700	0.25	2.0	9.1	8.6	80
1N3023	13	19	10	700	0.25	1.0	9.9	9.4	74
1N3024	15	17	14	700	0.25	1.0	11.4	10.8	63
1N3025	16	15.5	16	700	0.25	1.0	12.2	11.5	60
1N3026	18	14	20	750	0.25	0.5	13.7	13.0	52
1N3027	20	12.5	22	750	0.25	0.5	15.2	14.4	47
1N3028	22	11.5	23	750	0.25	0.5	16.7	15.8	43
1N3029	24	10.5	25	750	0.25	0.5	18.2	17.3	40
1N3030	27	9.5	35	750	0.25	0.5	20.6	19.4	34
1N3031	30	8.5	40	1000	0.25	0.5	22.8	21.6	31
1N3032	33	7.5	45	1000	0.25	0.5	25.1	23.8	28
1N3033	36	7.0	50	1000	0.25	0.5	27.4	25.9	26
1N3034	39	6.5	60	1000	0.25	0.5	29.7	28.1	23
1N3035	43	6.0	70	1500	0.25	0.5	32.7	31.0	21
1N3036	47	5.5	80	1500	0.25	0.5	35.8	33.8	19
1N3037	51	5.0	95	1500	0.25	0.5	38.8	36.7	18
1N3038	56	4.5	110	2000	0.25	0.5	42.6	40.3	17
1N3039	62	4.0	125	2000	0.25	0.5	47.1	44.6	15
1N3040	68	3.7	150	2000	0.25	0.5	51.7	49.0	14
1N3041	75	3.3	175	2000	0.25	0.5	56.0	54.0	12
1N3042	82	3.0	200	3000	0.25	0.5	62.2	59.0	11
1N3043	91	2.8	250	3000	0.25	0.5	69.2	65.5	10
1N3044	100	2.5	350	3000	0.25	0.5	76.0	72.0	9.0
1N3045	110	2.3	450	4000	0.25	0.5	83.6	79.2	8.3
1N3046	120	2.0	550	4500	0.25	0.5	91.2	86.4	8.0
1N3047	130	1.9	700	5000	0.25	0.5	98.8	93.6	6.9
1N3048	150	1.7	1000	6000	0.25	0.5	114.0	108.0	5.7
1N3049	160	1.6	1100	6500	0.25	0.5	121.6	115.2	5.4
1N3050	180	1.4	1200	7000	0.25	0.5	136.8	129.6	4.9
1N3051	200	1.2	1500	8000	0.25	0.5	152.0	144.0	4.6

* JEDEC Registered Data on 1N3821 thru 1N3830 and 1N3016 thru 1N3051

NOTE 1 – TOLERANCE AND TYPE NUMBER DESIGNATION

1N3821 thru 1N3830 – The JEDEC type numbers shown have a standard tolerance for the nominal zener voltage of ±10%. A standard tolerance of ±5% for individual units is also available and is indicated by adding suffix "A" to the standard type number.

1N3016 thru 1N3051 – The JEDEC type numbers shown have a standard tolerance of ±20% for the nominal zener voltage. Suffix "A" for ±10% units or "B" for ±5% units.

NOTE 2 – SPECIALS AVAILABLE INCLUDE:

(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES: To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±3%, ±2%, ±1%), the Motorola type number should be used.

1	M	5.1	A	Z	3
Device Description	Motorola	Nominal Voltage	1N3821 thru 1N3830 only	Zener Diode	Tolerance (±%)

EXAMPLE **1M5.1AZ3**

(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±2.0%, ±1.0%).

Zener diodes are available in sets consisting of two or more matched devices. The method for specifying matched sets is similar to the one described in (A) except that two additional suffixes are added to the code number described.

These devices are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set ordered.

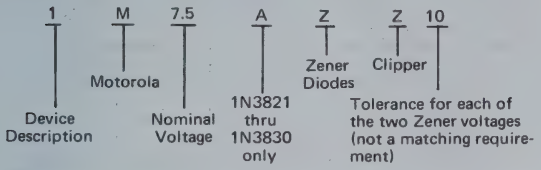
1	M	51	A	5	B	1
Device Description	Motorola	51 Volts (each device)	1N3821 thru 1N3830 only	Tolerance per device ±5% (omit for ±20% units)	Code	Overall Tolerance of set (±1%)

Code
A – Not used
B – Two devices in series
C – Three devices in series
D – Four devices in series

EXAMPLE **1M51Z5B1**

(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:



Example: 1M7.5AZZ10

NOTE 3 – ZENER VOLTAGE (V_Z) MEASUREMENT

Motorola guarantees the zener voltage when measured at 90 seconds while maintaining the lead temperature (T_L) at 30°C ± 1°C, 3/8″ from the diode body.

NOTE 4 – ZENER IMPEDANCE (Z_Z) DERIVATION

The zener impedance is derived from the 60 cycle ac voltage, which results when an ac current having an rms value equal to 10% of the dc zener current (I_{ZT} or I_{ZK}) is superimposed on I_{ZT} or I_{ZK}.

NOTE 5 – REVERSE LEAKAGE CURRENT I_R

Reverse leakage currents are guaranteed only for 5% and 10% zener diodes and are measured at V_R as shown in the Electrical Characteristics Table.

NOTE 6 – MAXIMUM ZENER CURRENT RATINGS (I_{ZM})

1N3821 thru 1N3830 – Maximum zener current ratings are based on maximum voltage of 10% tolerance units.

1N3016 thru 1N3051 – Maximum zener current ratings are based on maximum voltage of 5% tolerance units.

NOTE 7 – SURGE CURRENT (i_r)

Surge current is specified as the maximum allowable peak, non-recurrent square-wave current with a specified pulse width, PW. The data presented in Figures 8 and 9 may be used to find the maximum surge current for a square wave of any pulse width between 0.01 ms and 1000 ms.

APPLICATION NOTE

Since the actual voltage available from a given zener diode is temperature dependent, it is necessary to determine junction temperature under any set of operating conditions in order to calculate its value. The following procedure is recommended:

Lead Temperature, T_L, should be determined from:

$$T_L = \theta_{LA} P_D + T_A$$

θ_{LA} is the lead-to-ambient thermal resistance (°C/W) and P_D is the power dissipation. The value for θ_{LA} will vary and depends on the device mounting method. θ_{LA} is generally 30-40°C/W for the various clips and tie points in common use and for printed circuit board wiring.

The temperature of the lead can also be measured using a thermocouple placed on the lead as close as possible to the tie point. The thermal mass connected to the tie point is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_L, the junction temperature may be determined by:

$$T_J = T_L + \Delta T_{JL}$$

ΔT_{JL} is the increase in junction temperature above the lead temperature and may be found from Figure 6 for a train of power pulses (L = 3/8 inch) or from Figure 7 for dc power.

$$\Delta T_{JL} = \theta_{JL} P_D$$

For worst-case design, using expected limits of I_Z, limits of P_D and the extremes of $T_J(\Delta T_J)$ may be estimated. Changes in voltage, V_Z, can then be found from:

$$\Delta V = \theta_{VZ} \Delta T_J$$

θ_{VZ}, the zener voltage temperature coefficient, is found from Figures 2 and 3.

Under high power-pulse operation, the zener voltage will vary with time and may also be affected significantly by the zener resistance. For best regulation, keep current excursions as low as possible.

Data of Figure 6 should not be used to compute surge capability. Surge limitations are given in Figure 8. They are lower than would be expected by considering only junction temperature, as current crowding effects cause temperatures to be extremely high in small spots resulting in device degradation should the limits of Figure 8 be exceeded.

TEMPERATURE COEFFICIENTS AND VOLTAGE REGULATION

(90% OF THE UNITS ARE IN THE RANGES INDICATED)

FIGURE 2 – TEMPERATURE COEFFICIENT-RANGE FOR UNITS TO 12 VOLTS

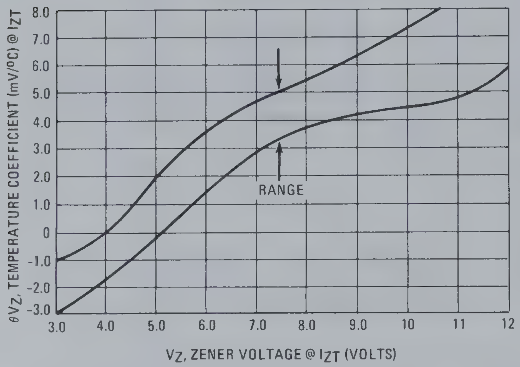


FIGURE 3 – TEMPERATURE COEFFICIENT-RANGE FOR UNITS 10 TO 220 VOLTS

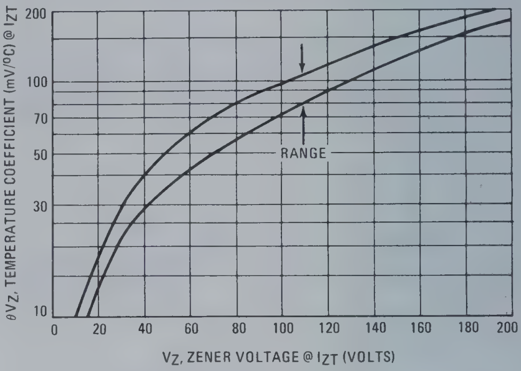


FIGURE 4 – TYPICAL VOLTAGE REGULATION

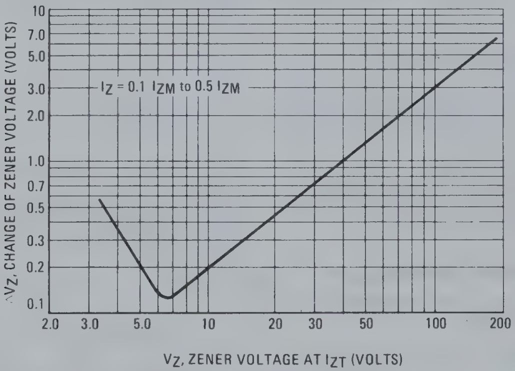


FIGURE 5 – MAXIMUM REVERSE LEAKAGE
(95% OF THE UNITS ARE BELOW THE VALUES SHOWN)

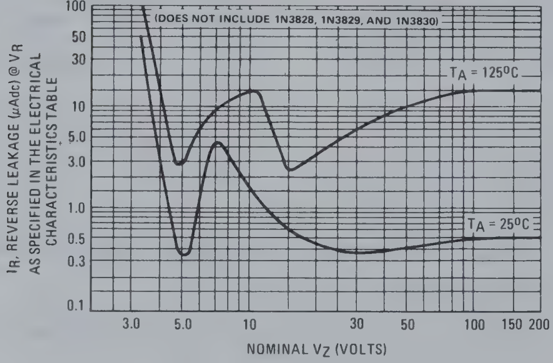


FIGURE 6 – TYPICAL THERMAL RESPONSE L, LEAD LENGTH = 3/8 INCH

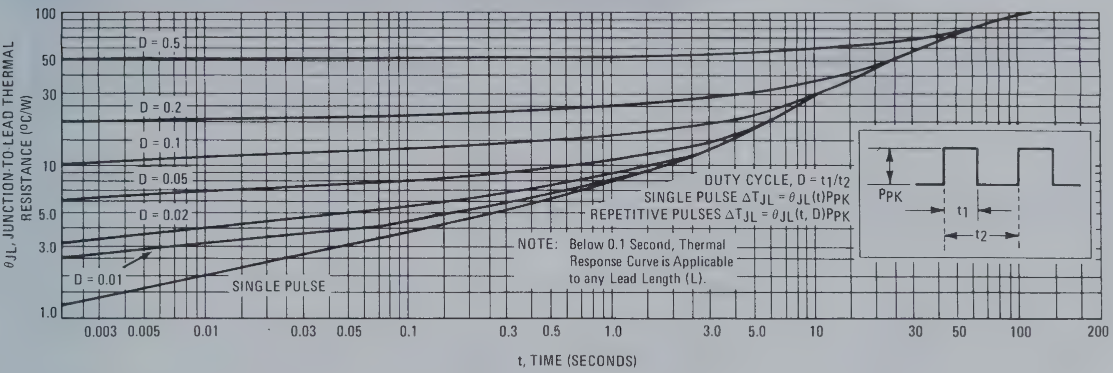


FIGURE 7 – TYPICAL THERMAL RESISTANCE

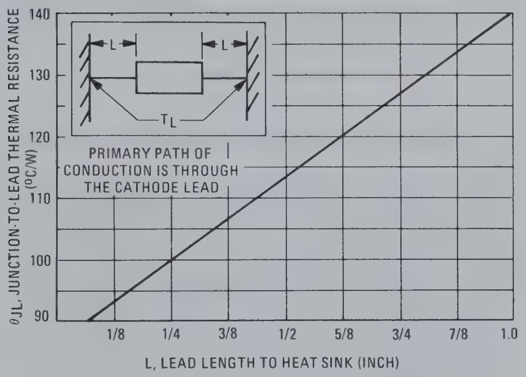


FIGURE 8 – MAXIMUM NON-REPETITIVE SURGE CURRENT

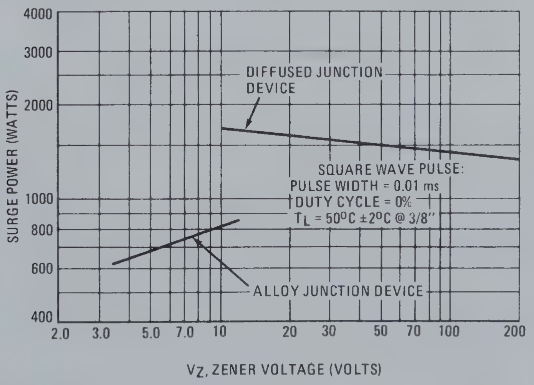


FIGURE 9 – SURGE POWER FACTOR

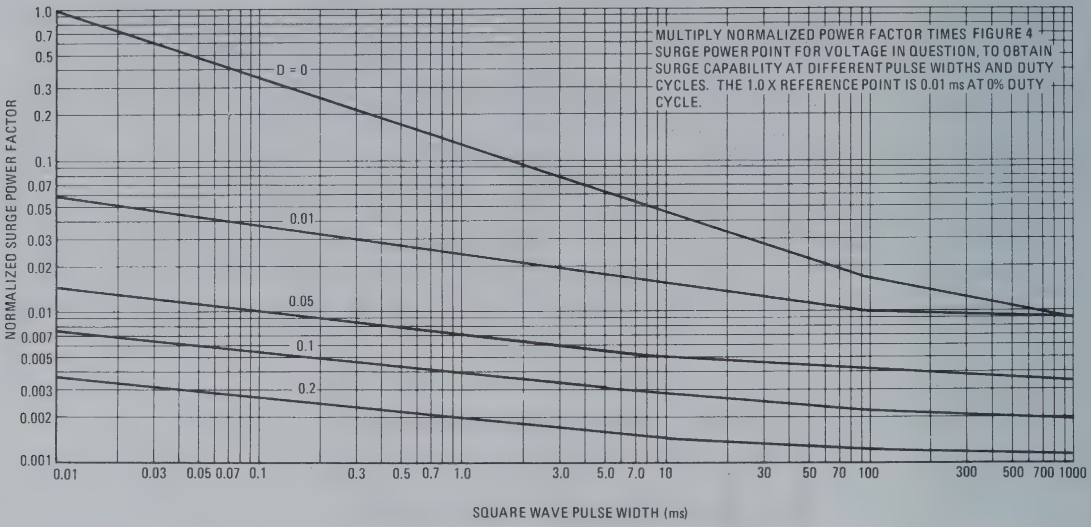
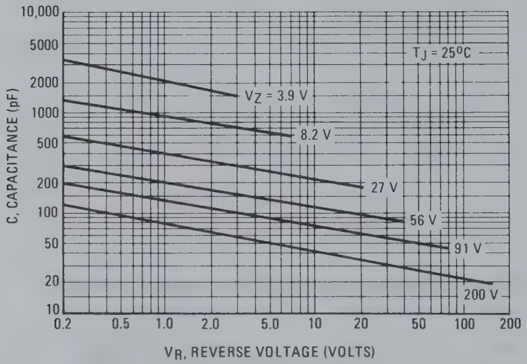


FIGURE 10 – TYPICAL CAPACITANCE



1N3879 thru 1N3883
MR1366

Designers Data Sheet

STUD MOUNTED
FAST RECOVERY POWER RECTIFIERS

. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference, sonar power supplies and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

Designer's Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

*MAXIMUM RATINGS

Rating	Symbol	1N3879	1N3880	1N3881	1N3882	1N3883	MR1366	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	300	400	600	Volts
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	250	350	450	650	Volts
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	210	280	420	Volts
Average Rectified Forward Current (Single phase, resistive load, $T_C = 100^{\circ}C$)	I_O	← 6.0 →						Amps
Non-Repetitive Peak Surge Current (surge applied at rated load continuous)	I_{FSM}	← 150 → (one cycle)						Amps
Operating Junction Temperature Range	T_J	← -65 to +150 →						°C
Storage Temperature Range	T_{stg}	← -65 to +175 →						°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	3.0	°C/W

Motorola guarantees the listed value, although parts having higher values of thermal resistance will meet the current rating. Thermal resistance is not required by the JEDEC registration.

*ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Instantaneous Forward Voltage ($I_F = 19$ Amp, $T_J = 150^{\circ}C$)	v_F		1.2	1.5	Volts
Forward Voltage (I_F – 6.0 Amp, $T_C = 25^{\circ}C$)	V_F	–	1.0	1.2	Volts
Reverse Current (rated dc voltage) $T_C = 25^{\circ}C$ $T_C = 100^{\circ}C$	I_R	– –	10 0.5	15 1.0	µA mA

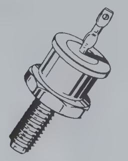
REVERSE RECOVERY CHARACTERISTICS

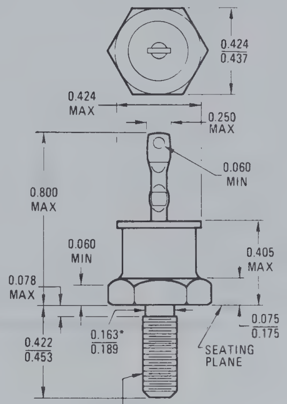
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Recovery Time *($I_{FM} = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16) ($I_{FM} = 36$ Amp, di/dt = 25 A/µs, Figure 17)	t_{rr}	 – –	 100 200	 200 400	ns
Reverse Recovery Current *($I_F = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16)	$I_{RM(REC)}$	–	–	2.0	Amp

*Indicates JEDEC Registered Data for 1N3879 Series.

FAST RECOVERY
POWER RECTIFIERS

50-600 VOLTS
6 AMPERES





*Dimension is a diameter
All JEDEC dimensions and notes apply

CASE 56B
DO-4

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed

FINISH: All external surfaces corrosion resistant and readily solderable

POLARITY: Cathode to Case

WEIGHT: 5.6 Grams (approximately)

FIGURE 1 – FORWARD VOLTAGE

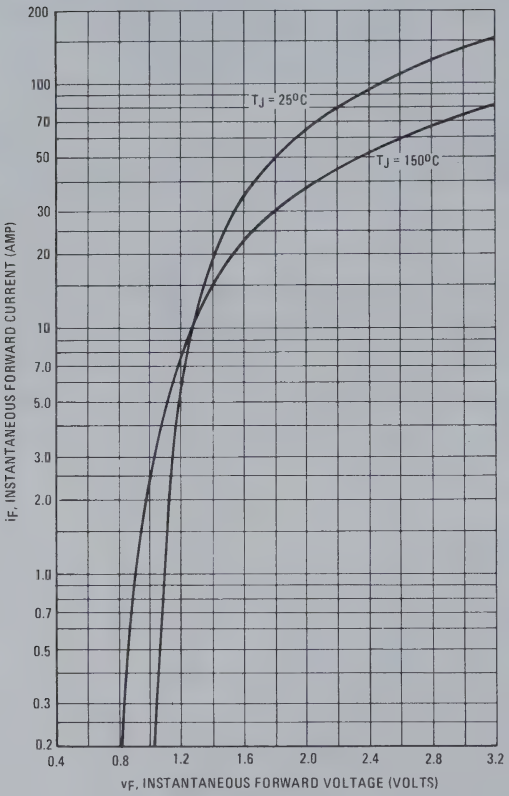
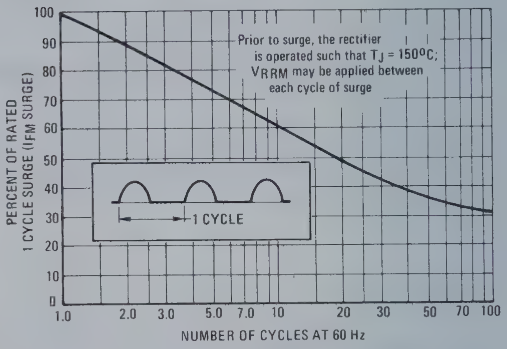
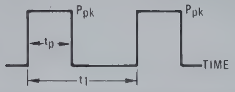


FIGURE 2 – MAXIMUM SURGE CAPABILITY



NOTE 1



DUTY CYCLE, $D = t_p/t_1$
PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended

The temperature of the case should be measured using a thermocouple placed on the case at the temperature reference point (see Note 3). The thermal mass connected to the case is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_C, the junction temperature may be determined by:

$$T_J = T_C + \quad T_{JC}$$

where T_{JC} is the increase in junction temperature above the case temperature. It may be determined by:

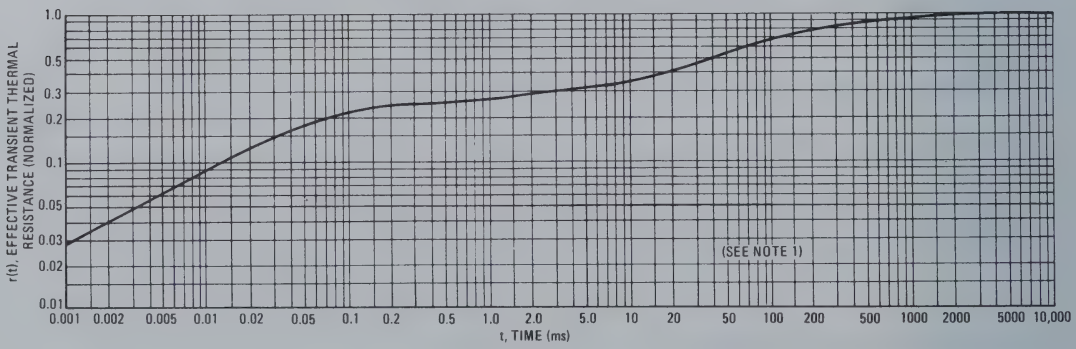
$$\Delta T_{JC} = P_{pk} \cdot R_{\theta JC} [D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) - r(t_1)]$$

where

$r(t)$ = normalized value of transient thermal resistance at time, t, from Figure 3, i.e.:

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

FIGURE 3 – THERMAL RESPONSE



SINE WAVE INPUT

FIGURE 4 – FORWARD POWER DISSIPATION

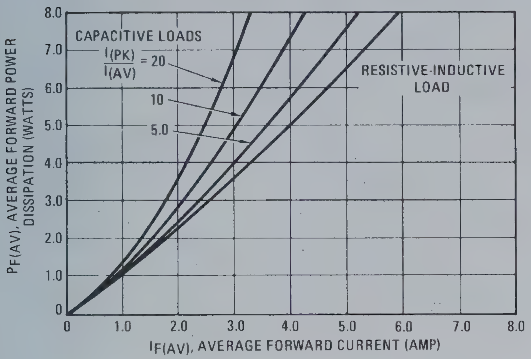


FIGURE 6 – CURRENT DERATING

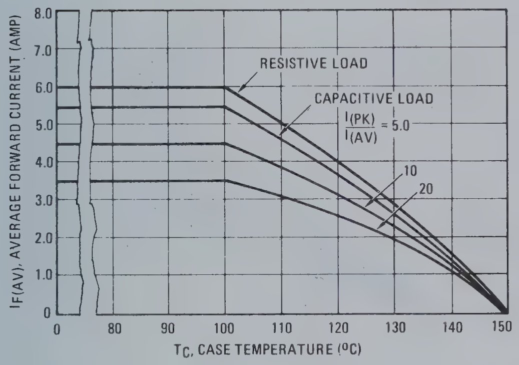
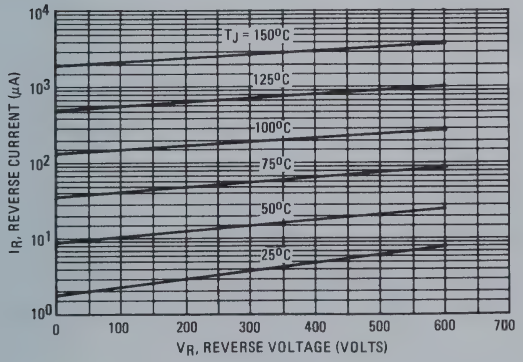


FIGURE 8 – TYPICAL REVERSE CURRENT



SQUARE WAVE INPUT

FIGURE 5 – FORWARD POWER DISSIPATION

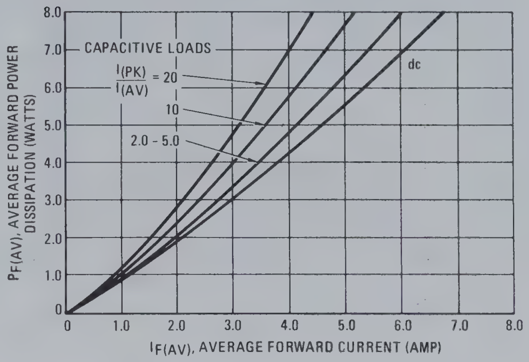


FIGURE 7 – CURRENT DERATING

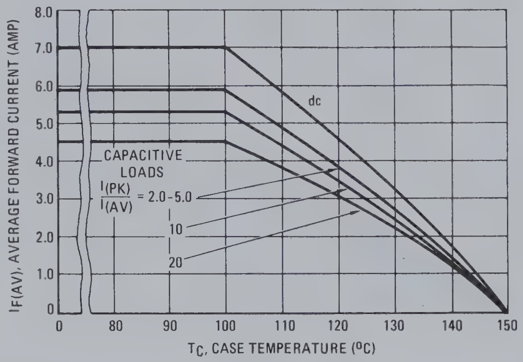
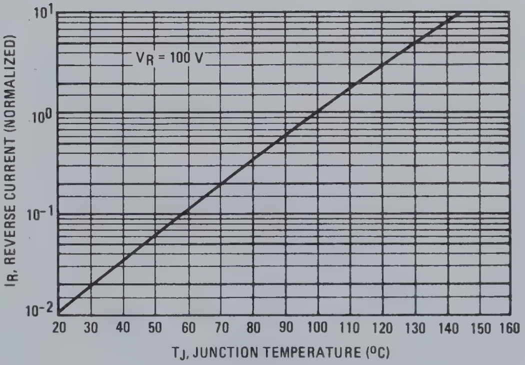


FIGURE 9 – NORMALIZED REVERSE CURRENT



TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 10 – FORWARD RECOVERY TIME

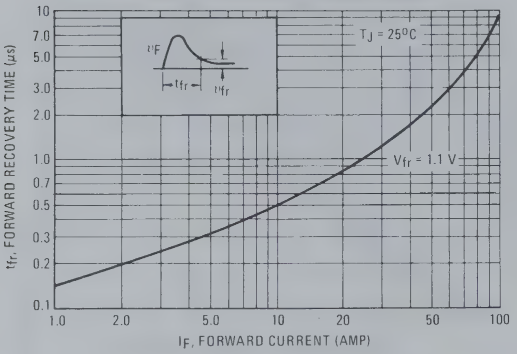
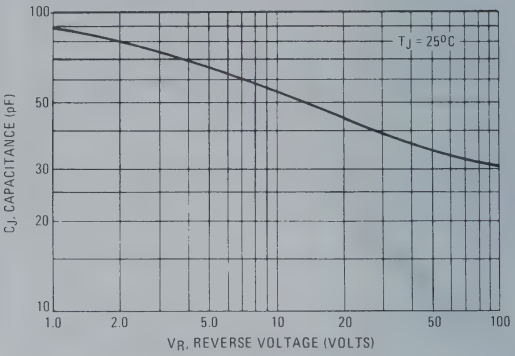


FIGURE 11 – JUNCTION CAPACITANCE



TYPICAL RECOVERED STORED CHARGE DATA

(SEE NOTE 2)

FIGURE 12 – T_J = 25°C

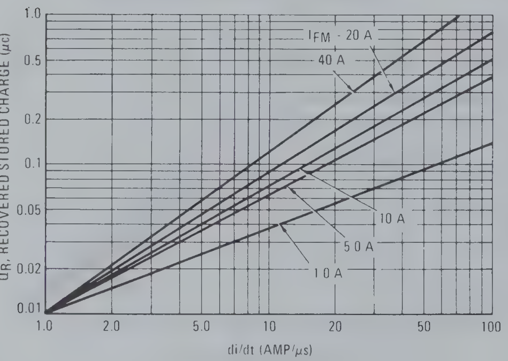


FIGURE 13 – T_J = 75°C

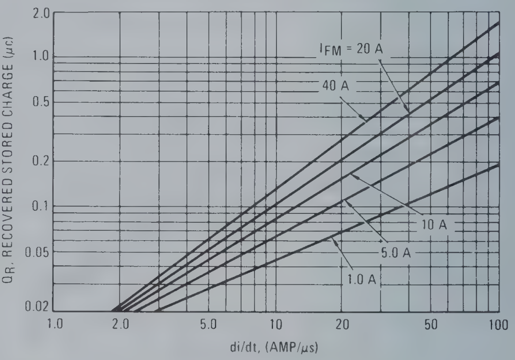


FIGURE 14 – T_J = 100°C

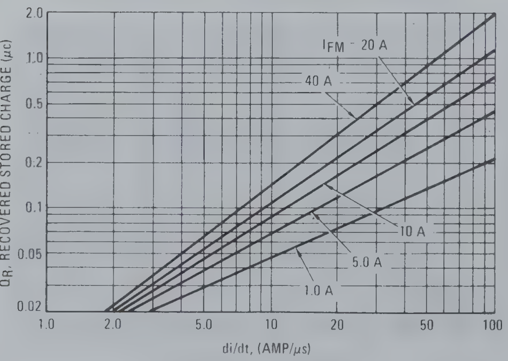


FIGURE 15 – T_J = 150°C

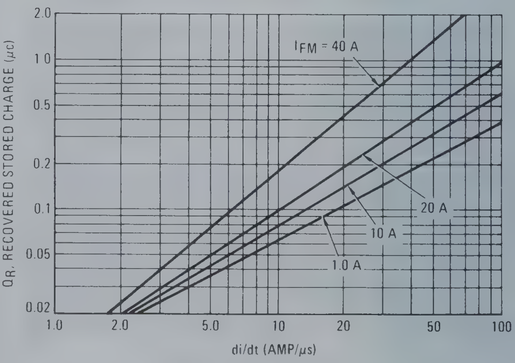
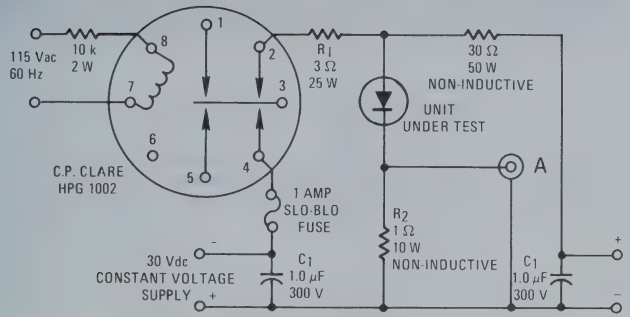


FIGURE 16 – REVERSE RECOVERY CIRCUIT


115 Vac
60 Hz
10 k
2 W
C.P. CLARE
HPG 1002
1
2
3
4
5
6
7
8
R1
3 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1 AMP
SLO-BLO
FUSE
R2
1 Ω
10 W
NON-INDUCTIVE
30 Vdc
CONSTANT VOLTAGE
SUPPLY
C1
1.0 μF
300 V
C1
1.0 μF
300 V
+
–

A – TEKTRONIX 545A, K PLUG IN
PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 – ADJUSTED FOR 1.4 Ω BETWEEN
POINT 2 OF RELAY AND RECTIFIER
INDUCTANCE ≈ 38 μH

R_2 – TEN-1 W, 10 Ω, 1% CARBON CORE
IN PARALLEL

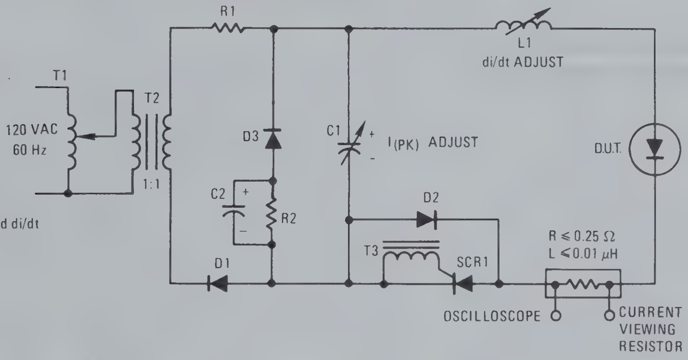
$T_A = 25 {}^{+10}_{-0}$ °C FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
Z_{out} = 1½ Ω MAX, DC to 2 kHz

FIGURE 17 – JEDEC REVERSE RECOVERY CIRCUIT

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4933
SCR1 = MCR729-10
C1 = 0.5 to 50 μF
C2 ≈ 4000 μF
L1 = 1.0 - 27 μH
T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)


R1
L1
di/dt ADJUST
T1
T2
120 VAC
60 Hz
1:1
D3
C1
I(PK) ADJUST
D.U.T.
C2
R2
D2
T3
SCR1
D1
R ≤ 0.25 Ω
L ≤ 0.01 μH
OSCILLOSCOPE
CURRENT
VIEWING
RESISTOR

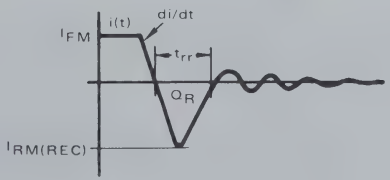
NOTE 2

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using I_F = 1.0 A, V_R = 30 V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.


I_FM
i(t)
di/dt
t_rr
Q_R
I_RM(REC)

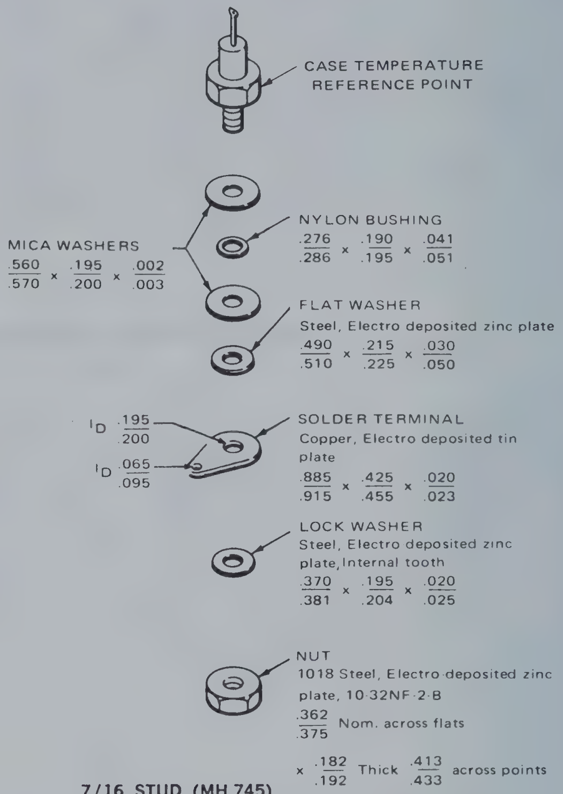
From stored charge curves versus di/dt, recovery time (t_{rr}) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

NOTE 3

INSULATING HARDWARE KIT AVAILABLE UPON REQUEST


CASE TEMPERATURE REFERENCE POINT
MICA WASHERS
.560/.570 x .195/.200 x .002/.003
NYLON BUSHING
.276/.286 x .190/.195 x .041/.051
FLAT WASHER
Steel, Electro deposited zinc plate
.490/.510 x .215/.225 x .030/.050
ID .195/.200
ID .065/.095
SOLDER TERMINAL
Copper, Electro deposited tin plate
.885/.915 x .425/.455 x .020/.023
LOCK WASHER
Steel, Electro deposited zinc plate, Internal tooth
.370/.381 x .195/.204 x .020/.025
NUT
1018 Steel, Electro-deposited zinc plate, 10-32NF-2-B
.362/.375 Nom. across flats
x .182/.192 Thick .413/.433 across points

7/16 STUD (MH 745)

CASE TO HEAT SINK THERMAL RESISTANCE UNDER VARIOUS CONDITIONS:

Metal-to-Metal		Mica Insulation	
Dry	Lubrication	Dry	Lubrication
0.41	0.22	1.24	1.06

Torque: 15 in-lbs

1N3889 thru 1N3893
MR1376

Designers Data Sheet

STUD MOUNTED
FAST RECOVERY POWER RECTIFIERS

. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference, sonar power supplies and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

Designer's Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

*MAXIMUM RATINGS

Rating	Symbol	1N3889	1N3890	1N3891	1N3892	1N3893	MR1376	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	300	400	600	Volts
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	250	350	450	650	Volts
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	210	280	420	Volts
Average Rectified Forward Current (Single phase, resistive load, $T_C = 100^oC$)	I_O	← 12 →						Amps
Non-Repetitive Peak Surge Current (Surge applied at rated load conditions)	I_{FSM}	← 200 → (one cycle)						Amp
Operating Junction Temperature Range	T_J	← −65 to +150 →						°C
Storage Temperature Range	T_{stg}	← −65 to +175 →						°C

THERMAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	2.0	°C/W

Motorola guarantees the listed value, although parts having higher values of thermal resistance will meet the current rating. Thermal resistance is not required by the JEDEC registration.

*ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Instantaneous Forward Voltage ($I_F = 38$ Amp, $T_J = 150^oC$)	v_F	–	1.2	1.5	Volts
Forward Voltage ($I_F = 12$ Amp, $T_C = 25^oC$)	V_F	–	1.0	1.4	Volts
Reverse Current (rated dc voltage) $T_C = 25^oC$ $T_C = 100^oC$	I_R	– –	10 0.5	15 1.0	µA mA

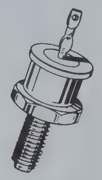
*REVERSE RECOVERY CHARACTERISTICS

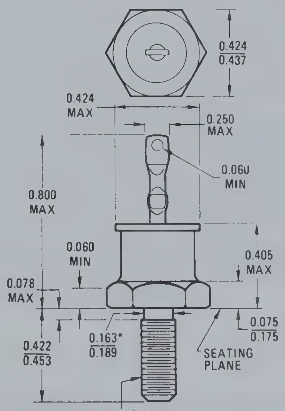
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Recovery Time ($I_F = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16) ($I_{FM} = 36$ Amp, di/dt = 25 A/µs, Figure 17)	t_{rr}	 – –	 100 200	 200 400	ns
Reverse Recovery Current ($I_F = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16)	$I_{RM(REC)}$	–	–	2.0	Amp

*Indicates JEDEC Registered Data for 1N3889 Series.

FAST RECOVERY
POWER RECTIFIERS

50-600 VOLTS
12 AMPERES





*Dimension is a diameter
All JEDEC dimensions and notes apply

CASE 56B
DO-4

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed

FINISH: All external surfaces corrosion resistant and readily solderable

POLARITY: Cathode to Case

WEIGHT: 5.6 grams (approximately)

FIGURE 1 – FORWARD VOLTAGE

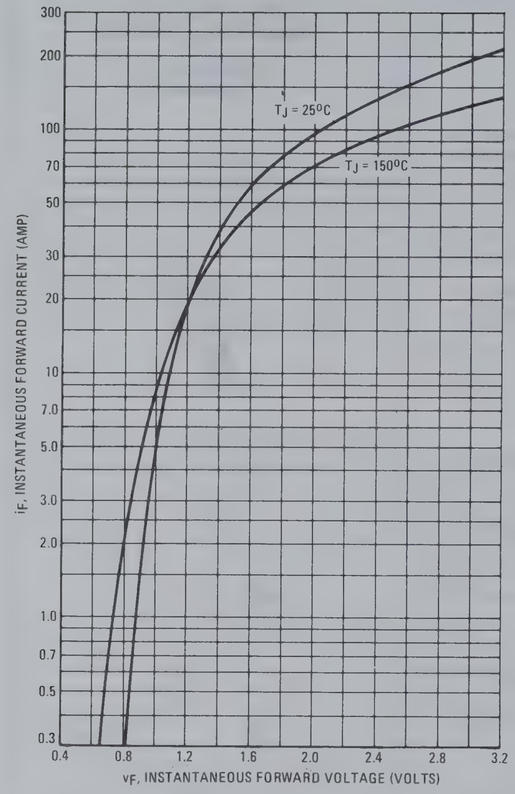
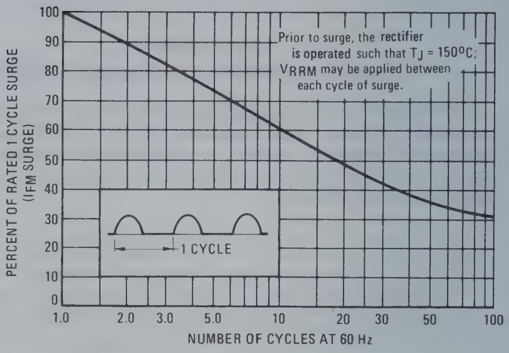
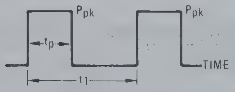


FIGURE 2 – MAXIMUM SURGE CAPABILITY



NOTE 1



DUTY CYCLE, $D = t_p/t_1$
PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended

The temperature of the case should be measured using a thermocouple placed on the case at the temperature reference point (see Note 3). The thermal mass connected to the case is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_C, the junction temperature may be determined by:

$$T_J = T_C + \Delta T_{JC}$$

where T_{JC} is the increase in junction temperature above the case temperature. It may be determined by

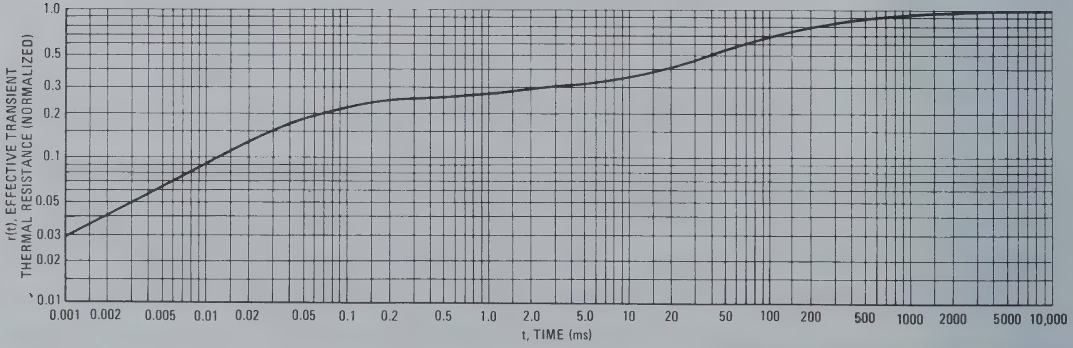
$$\Delta T_{JC} = P_{pk} \cdot R_{\theta JC} [D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) \quad r(t_1)]$$

where

$r(t)$ = normalized value of transient thermal resistance at time, t, from Figure 3, i.e.

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

FIGURE 3 – THERMAL RESPONSE



SINE WAVE INPUT

FIGURE 4 – FORWARD POWER DISSIPATION

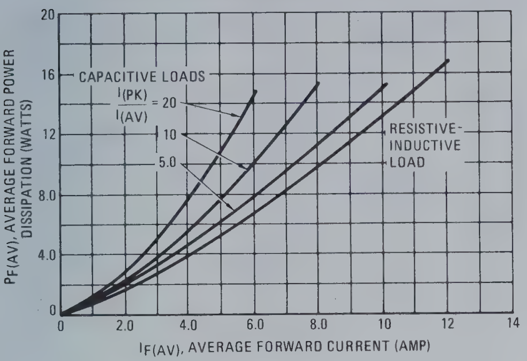


FIGURE 6 – CURRENT DERATING

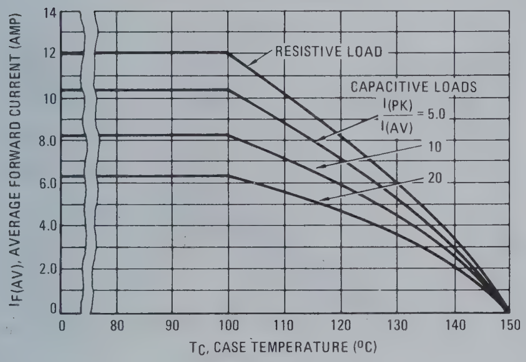
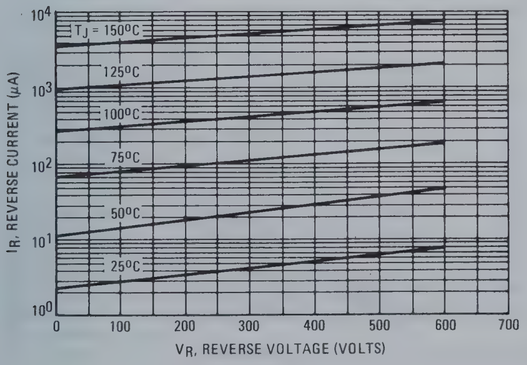


FIGURE 8 – TYPICAL REVERSE CURRENT



SQUARE WAVE INPUT

FIGURE 5 – FORWARD POWER DISSIPATION

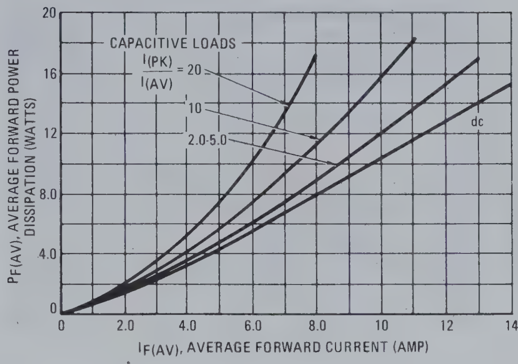


FIGURE 7 – CURRENT DERATING

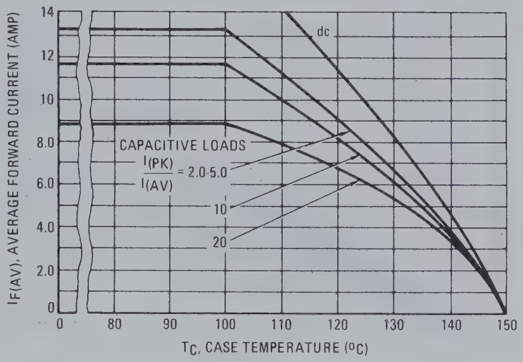
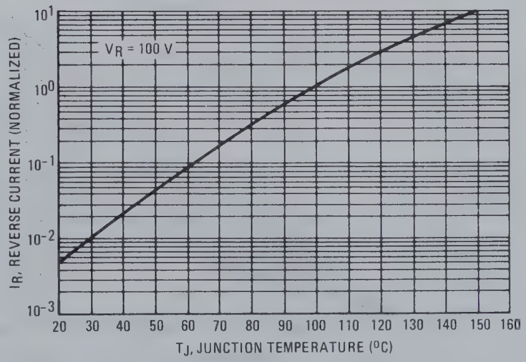


FIGURE 9 – NORMALIZED REVERSE CURRENT



TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 10 – FORWARD RECOVERY TIME

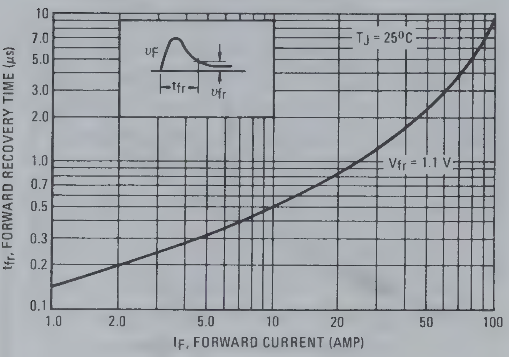
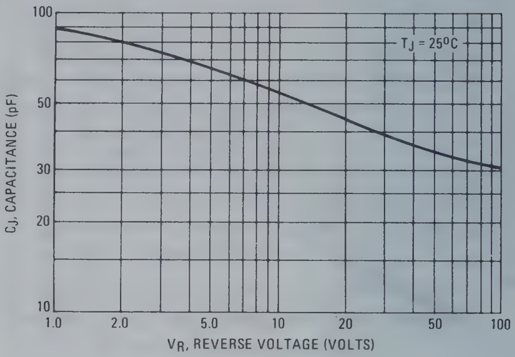


FIGURE 11 – JUNCTION CAPACITANCE



TYPICAL RECOVERED STORED CHARGE DATA

(See Note 2)

FIGURE 12 – T_J = 25°C

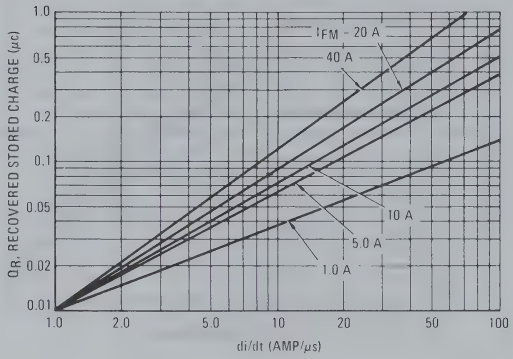


FIGURE 13 – T_J = 75°C

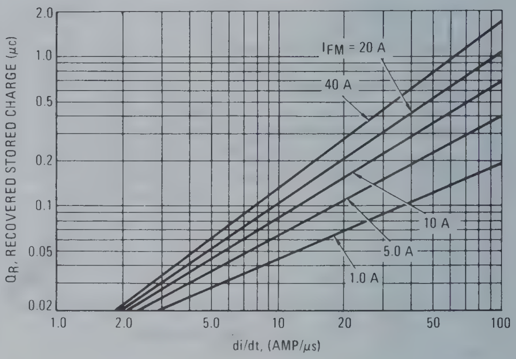


FIGURE 14 – T_J = 100°C

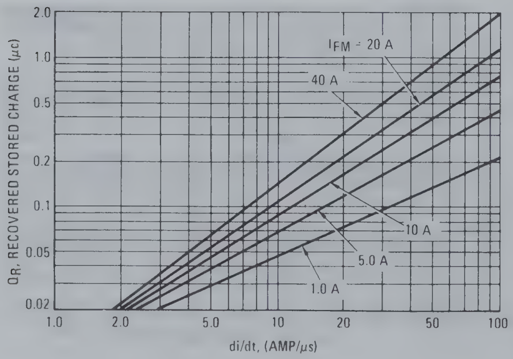


FIGURE 15 – T_J = 150°C

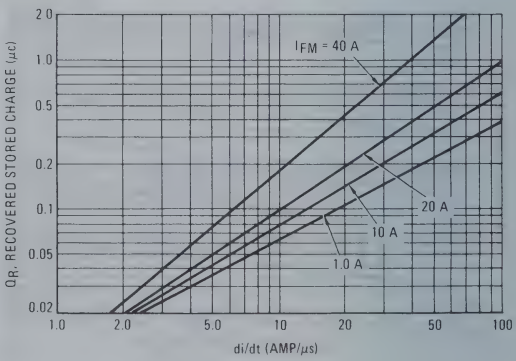
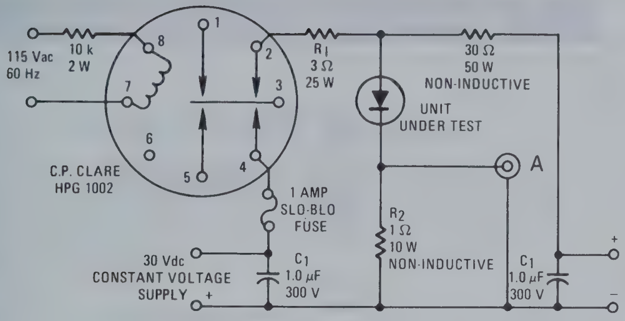


FIGURE 16 – REVERSE RECOVERY CIRCUIT


115 Vac
60 Hz
10 k
2 W
1
2
3
4
5
6
7
8
C.P. CLARE
HPG 1002
R_1
3 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1 AMP
SLO-BLO
FUSE
R_2
1 Ω
10 W
NON-INDUCTIVE
30 Vdc
CONSTANT VOLTAGE
SUPPLY
+
C_1
1.0 μF
300 V
C_1
1.0 μF
300 V
+
–

A – TEKTRONIX 545A, K PLUG IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 – ADJUSTED FOR 1.4 Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER INDUCTANCE ≈ 38 μH

R_2 – TEN-1 W, 10 Ω, 1% CARBON CORE IN PARALLEL

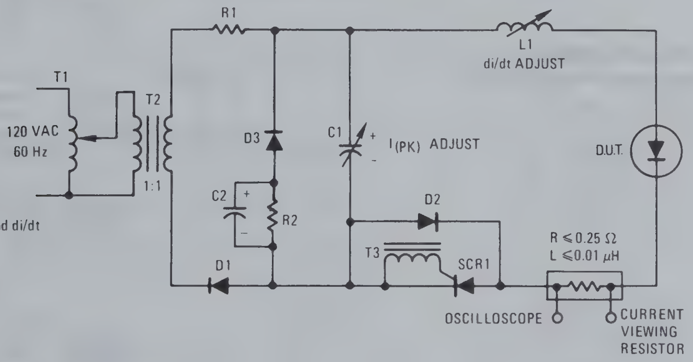
$T_A = 25 \, {}^{+10}_{-0} \, {}^{\circ}C$ FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
$Z_{out} = 1½ \, \Omega$ MAX, DC to 2 kHz

FIGURE 17 – JEDEC REVERSE RECOVERY CIRCUIT

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4933
SCR1 = MCR729-10
C1 = 0.5 to 50 μF
C2 ≈ 4000 μF
L1 = 1.0 - 27 μH
T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)


R1
L1
di/dt ADJUST
T1
T2
120 VAC
60 Hz
1:1
D3
C1
$I_{(PK)}$ ADJUST
+
-
D.U.T.
C2
+
-
R2
D2
T3
SCR1
D1
R ≤ 0.25 Ω
L ≤ 0.01 μH
OSCILLOSCOPE
CURRENT
VIEWING
RESISTOR

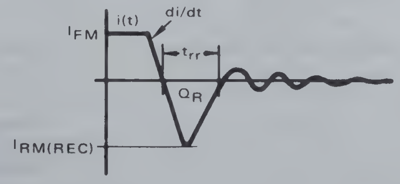
NOTE 2

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using I_F = 1.0 A, V_R = 30 V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.



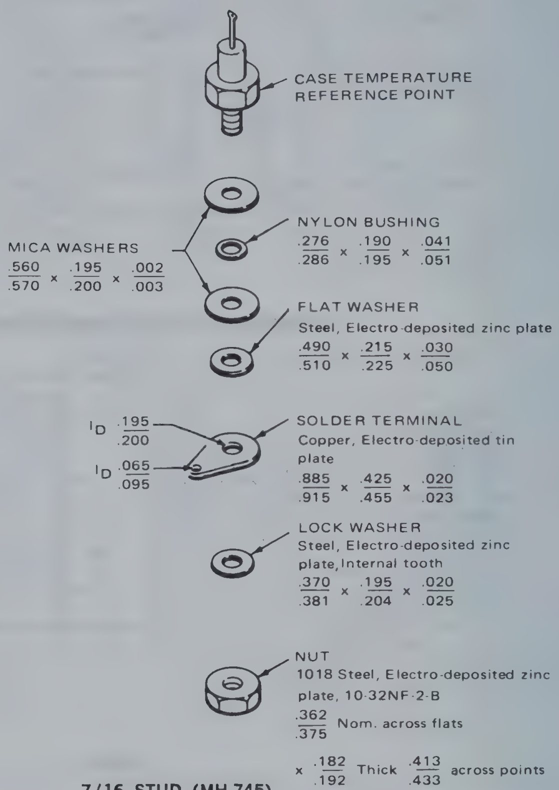
From stored charge curves versus di/dt, recovery time (t_{rr}) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

NOTE 3

INSULATING HARDWARE KIT AVAILABLE UPON REQUEST


CASE TEMPERATURE REFERENCE POINT
NYLON BUSHING
.276/.286 x .190/.195 x .041/.051
MICA WASHERS
.560/.570 x .195/.200 x .002/.003
FLAT WASHER
Steel, Electro-deposited zinc plate
.490/.510 x .215/.225 x .030/.050
ID .195/.200
ID .065/.095
SOLDER TERMINAL
Copper, Electro-deposited tin plate
.885/.915 x .425/.455 x .020/.023
LOCK WASHER
Steel, Electro-deposited zinc plate, Internal tooth
.370/.381 x .195/.204 x .020/.025
NUT
1018 Steel, Electro-deposited zinc plate, 10-32NF-2-B
.362/.375 Nom. across flats
x .182/.192 Thick .413/.433 across points

7/16 STUD (MH 745)

CASE TO HEAT SINK THERMAL RESISTANCE UNDER VARIOUS CONDITIONS

Metal-to-Metal		Mica Insulation	
Dry	Lubrication	Dry	Lubrication
0.41	0.22	1.24	1.06

TORQUE: 15 IN-LBS

1N3899 thru 1N3903
MR1386

Designers Data Sheet

STUD MOUNTED
FAST RECOVERY POWER RECTIFIERS

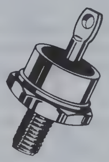
. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference, sonar power supplies and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

Designers Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

FAST RECOVERY POWER RECTIFIERS

50-600 VOLTS
20 AMPERES



*MAXIMUM RATINGS

Rating	Symbol	1N3899	1N3900	1N3901	1N3902	1N3903	MR1386	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	300	400	600	Volts
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	250	350	450	650	Volts
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	210	280	420	Volts
Average Rectified Forward Current (Single phase, resistive load, $T_C = 100^oC$)	I_O	20						Amps
Non-Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	250 (one cycle)						Amps
Operating Junction Temperature Range	T_J	-65 to +150						^oC
Storage Temperature Range	T_{stg}	-65 to +175						^oC

*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.8	$^oC/W$

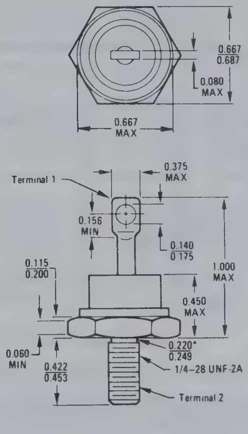
*ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Instantaneous Forward Voltage (I_F = 63 Amp, $T_J = 150^oC$)	v_F	–	1.2	1.5	Volts
Forward Voltage (I_F = 20 Amp, $T_C = 25^oC$)	V_F	–	1.1	1.4	Volts
Reverse Current (rated dc voltage) $T_C = 25^oC$	I_R	–	10	25	μA
$T_C = 100^oC$		–	0.5	1.0	mA

*REVERSE RECOVERY CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Recovery Time (I_F = 1.0 Amp to V_R = 30 Vdc, Figure 16)	t_{rr}	–	100	200	ns
(I_{FM} = 36 Amp, di/dt = 25 A/μs, Figure 17)		–	200	400	
Reverse Recovery Current (I_F = 1.0 Amp to V_R = 30 Vdc, Figure 16)	$I_{RM(REC)}$	–	–	2.0	Amp

*Indicates JEDEC Registered Data for 1N3899 Series.



*Dimension is a diameter.

All JEDEC dimensions and notes apply

CASE 257
DO-5

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed

FINISH: All external surfaces corrosion resistant and readily solderable

POLARITY: Cathode to Case

WEIGHT: 17 Grams (Approximately)

FIGURE 1 — FORWARD VOLTAGE

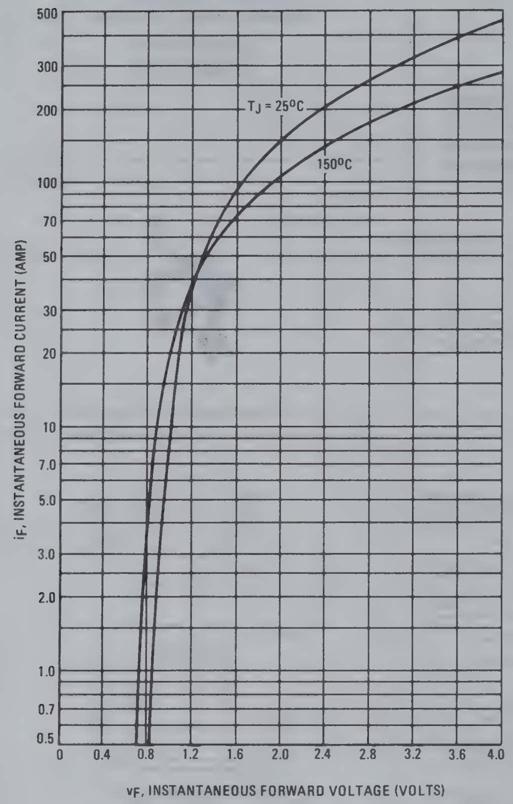
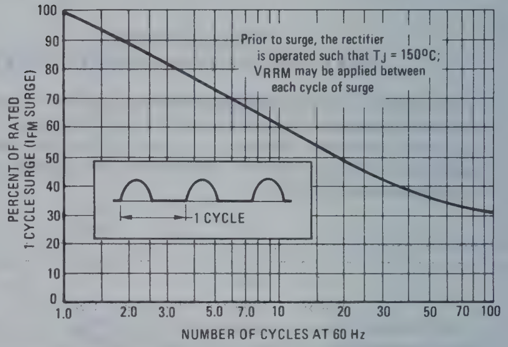
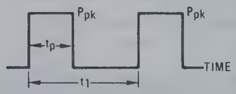


FIGURE 2 — MAXIMUM SURGE CAPABILITY



NOTE 1



DUTY CYCLE, $D = t_p/t_1$
PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the case should be measured using a thermocouple placed on the case at the temperature reference point (see Note 3). The thermal mass connected to the case is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_C, the junction temperature may be determined by:

$$T_J = T_C + \Delta T_{JC}$$

where ΔT_{JC} is the increase in junction temperature above the case temperature. It may be determined by:

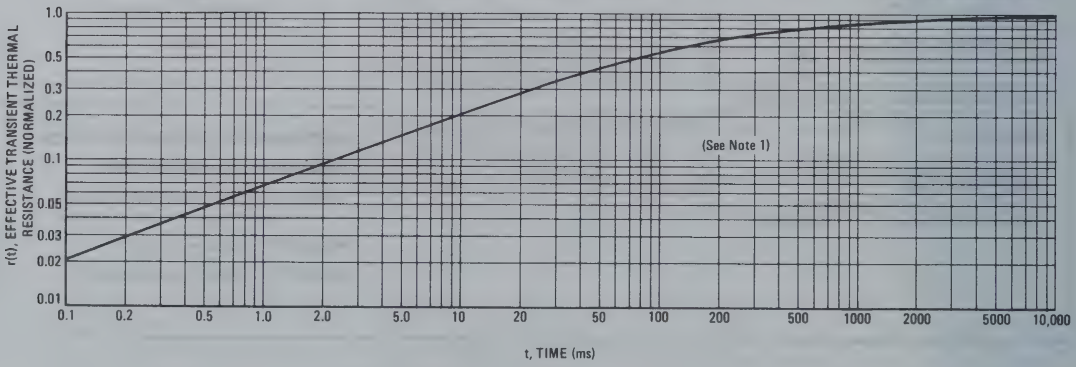
$$\Delta T_{JC} = P_{pk} \cdot R_{\theta JC} \left[D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) - r(t_1)\right]$$

where

$r(t)$ = normalized value of transient thermal resistance at time, t, from Figure 3, i.e.:

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

FIGURE 3 — THERMAL RESPONSE



SINE WAVE INPUT

FIGURE 4 – FORWARD POWER DISSIPATION

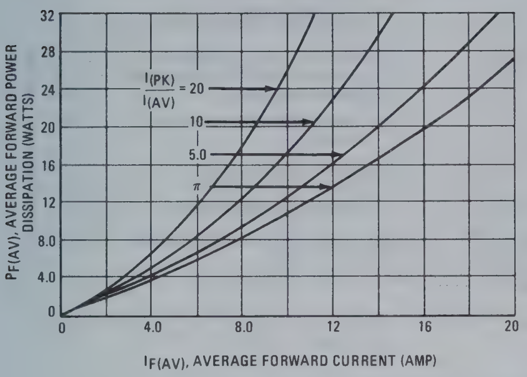


FIGURE 6 – CURRENT DERATING

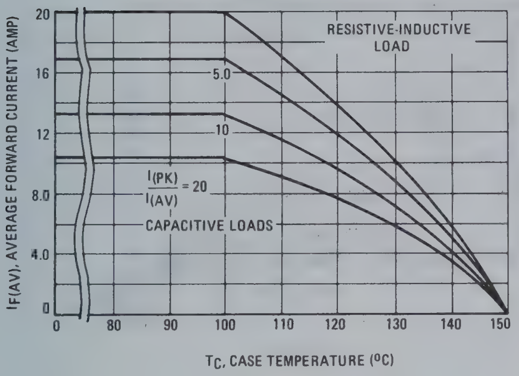
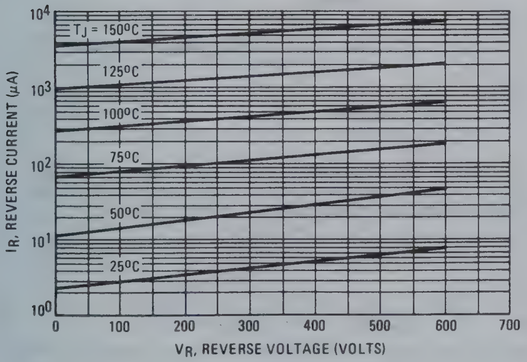


FIGURE 8 – TYPICAL REVERSE CURRENT



SQUARE WAVE INPUT

FIGURE 5 – FORWARD POWER DISSIPATION

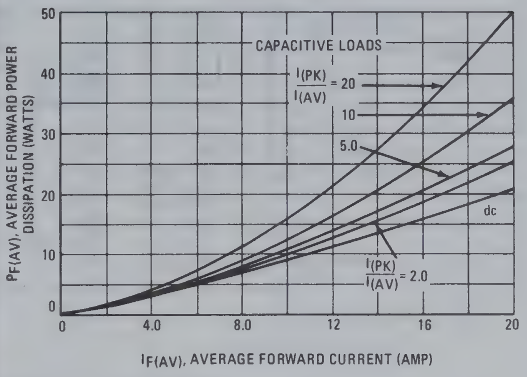


FIGURE 7 – CURRENT DERATING

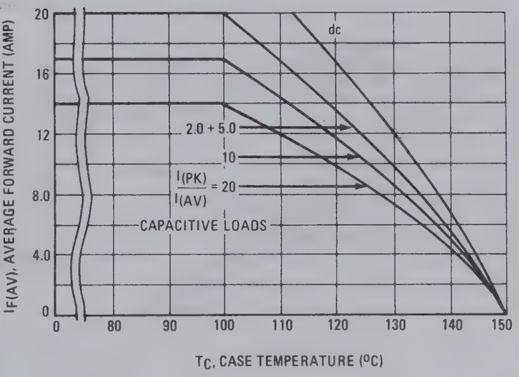


FIGURE 9 – NORMALIZED REVERSE CURRENT

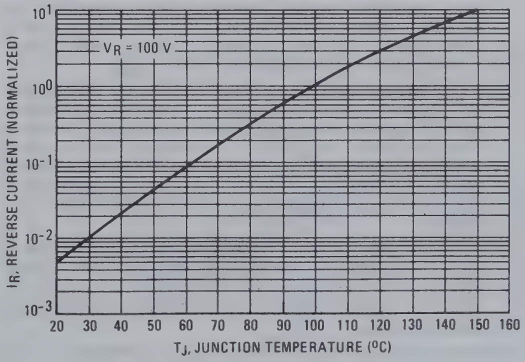
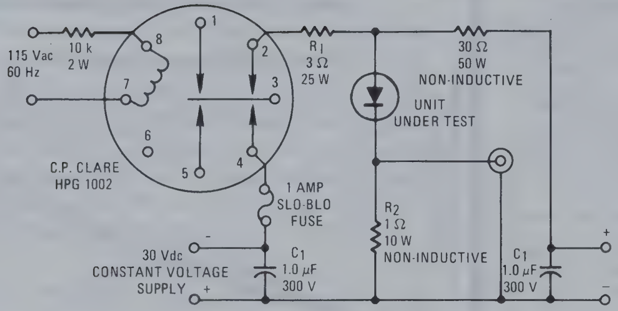


FIGURE 16 – REVERSE RECOVERY CIRCUIT


115 Vac
60 Hz
10 k
2 W
8
1
2
7
3
6
5
4
C.P. CLARE
HPG 1002
R1
3 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
1 AMP
SLO-BLO
FUSE
R2
1 Ω
10 W
NON-INDUCTIVE
30 Vdc
CONSTANT VOLTAGE
SUPPLY
C1
1.0 μF
300 V
C1
1.0 μF
300 V
+
-

A – TEKTRONIX 545A, K PLUG IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 – ADJUSTED FOR 1.4 Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER INDUCTANCE ≈ 38 μH

R_2 – TEN-1 W, 10 Ω, 1% CARBON CORE IN PARALLEL

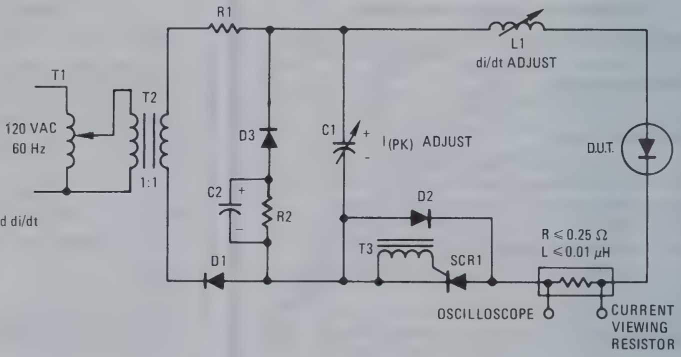
$T_A = 25\,^{+10}_{-0}\,^{\circ}C$ FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
$Z_{out} = 1\frac{1}{2}\ \Omega$ MAX, DC to 2 kHz

FIGURE 17 – JEDEC REVERSE RECOVERY CIRCUIT

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4933
SCR1 = MCR729-10
C1 = 0.5 to 50 μF
C2 ≈ 4000 μF
L1 = 1.0 - 27 μH
T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)


R1
T1
T2
120 VAC
60 Hz
1:1
D3
C1
I(PK) ADJUST
L1
di/dt ADJUST
D.U.T.
C2
R2
D1
D2
T3
SCR1
R ≤ 0.25 Ω
L ≤ 0.01 μH
OSCILLOSCOPE
CURRENT
VIEWING
RESISTOR

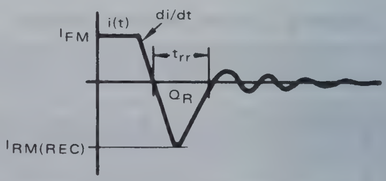
NOTE 2

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using I_F = 1.0 A, V_R = 30 V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.



From stored charge curves versus di/dt, recovery time (t_{rr}) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 10 – FORWARD RECOVERY TIME

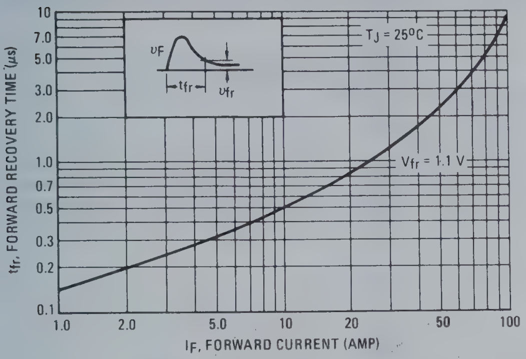
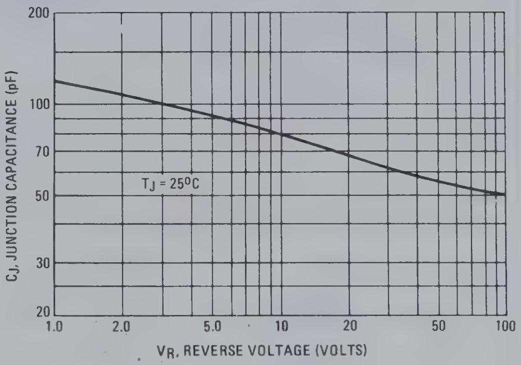


FIGURE 11 – JUNCTION CAPACITANCE



TYPICAL RECOVERED STORED CHARGE DATA

(See Note 2)

FIGURE 12 – T_J = 25°C

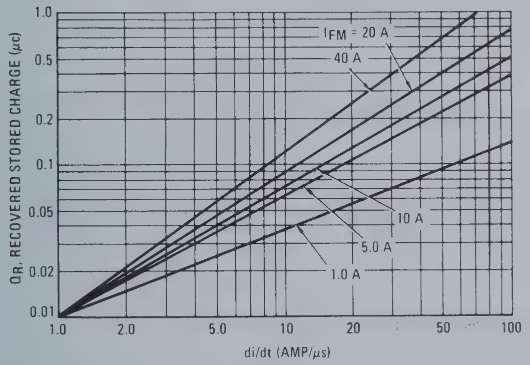
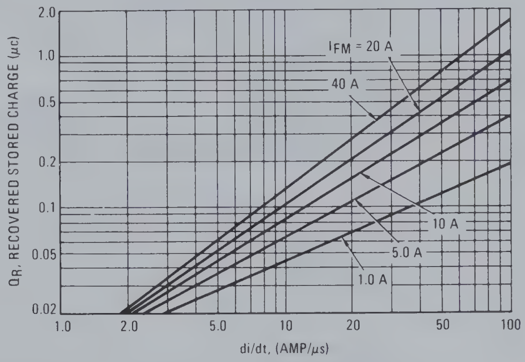


FIGURE 13 – T_J = 75°C



STORED CHARGE DATA

FIGURE 14 – T_J = 100°C

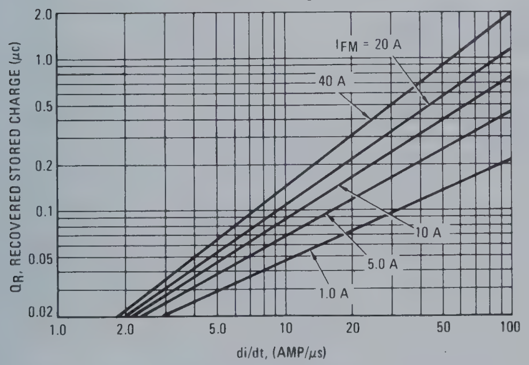
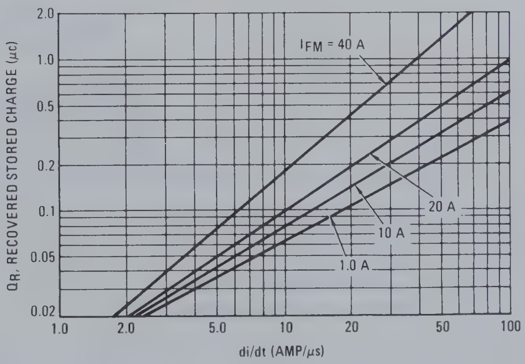
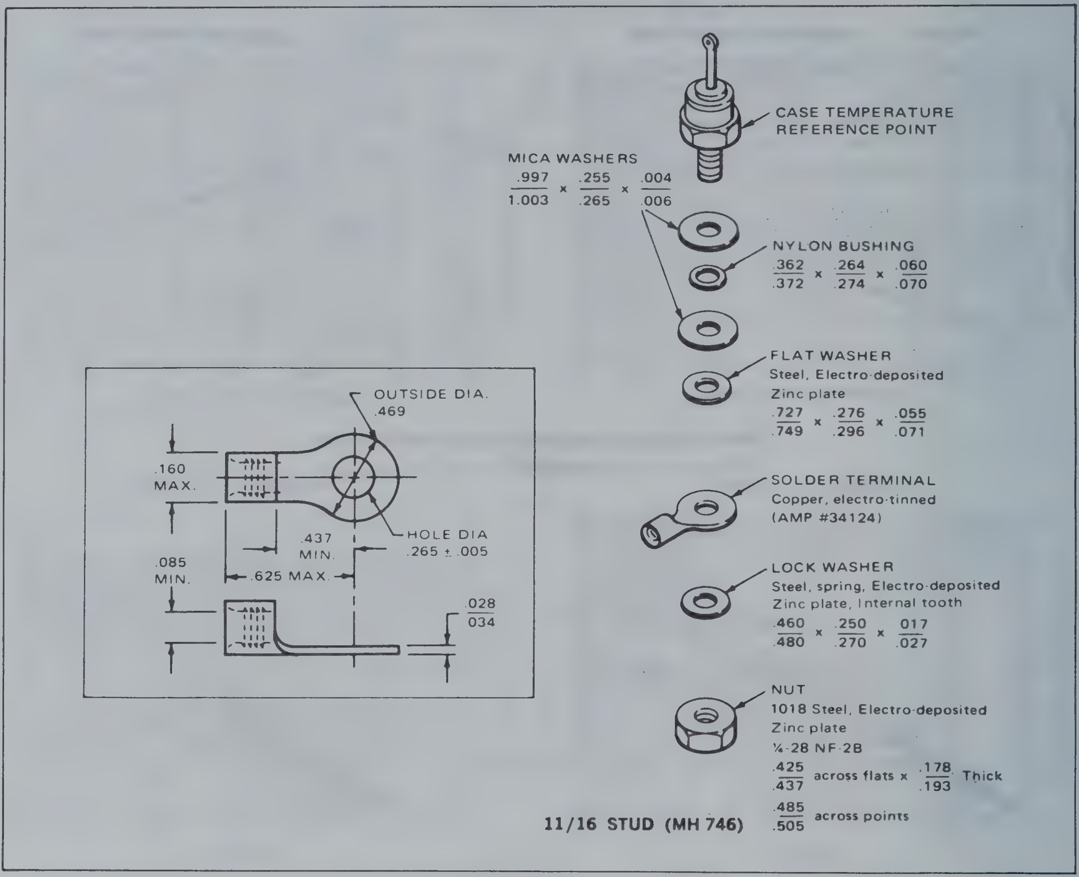


FIGURE 15 – T_J = 150°C



INSULATING HARDWARE KIT AVAILABLE UPON REQUEST


CASE TEMPERATURE REFERENCE POINT
MICA WASHERS
.997/1.003 x .255/.265 x .004/.006
NYLON BUSHING
.362/.372 x .264/.274 x .060/.070
FLAT WASHER
Steel, Electro-deposited Zinc plate
.727/.749 x .276/.296 x .055/.071
SOLDER TERMINAL
Copper, electro-tinned (AMP #34124)
LOCK WASHER
Steel, spring, Electro-deposited Zinc plate, Internal tooth
.460/.480 x .250/.270 x 017/.027
NUT
1018 Steel, Electro-deposited Zinc plate
¼-28 NF-2B
.425/.437 across flats x .178/.193 Thick
.485/.505 across points
OUTSIDE DIA. .469
.160 MAX.
.437 MIN.
HOLE DIA .265 ± .005
.085 MIN.
.625 MAX.
.028/034

11/16 STUD (MH 746)

CASE TO HEAT SINK THERMAL RESISTANCE UNDER VARIOUS CONDITIONS

Metal-to-Metal		Mica Insulation	
Dry	Lubrication	Dry	Lubrication
0.38	0.20	0.89	0.70

TORQUE: 25 IN LBS

1N3909 thru 1N3913
MR1396

Designers Data Sheet

STUD MOUNTED
FAST RECOVERY POWER RECTIFIERS

. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference, sonar power supplies and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

Designer's Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

*MAXIMUM RATINGS

Rating	Symbol	1N3909	1N3910	1N3911	1N3912	1N3913	MR1396	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	300	400	600	Volts
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	250	350	450	650	Volts
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	210	280	420	Volts
Average Rectified Forward Current (Single phase, resistive load, $T_C = 100^{o}C$)	I_O	← 30 →						Amps
Non-Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	← 300 →						Amp
Operating Junction Temperature Range	T_J	← -65 to +150 →						^{o}C
Storage Temperature Range	T_{stg}	← -65 to +175 →						^{o}C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.2	$^{o}C/W$

*ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Instantaneous Forward Voltage ($I_F = 93$ Amp, $T_J = 150^{o}C$)	v_F	—	1.2	1.5	Volts
Forward Voltage ($I_F = 30$ Amp, $T_C = 25^{o}C$)	V_F	—	1.1	1.4	Volts
Reverse Current (rated dc voltage) $T_C = 25^{o}C$ $T_C = 100^{o}C$	I_R	— —	10 0.5	25 1.0	μA mA

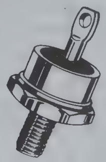
*REVERSE RECOVERY CHARACTERISTICS

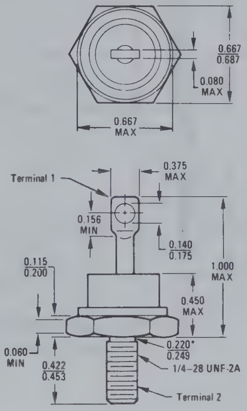
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Recovery Time ($I_F = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16) ($I_{FM} = 36$ Amp, di/dt = 25 A/μs, Figure 17)	t_{rr}	 — —	 100 200	 200 400	ns
Reverse Recovery Current ($I_F = 1.0$ Amp to $V_R = 30$ Vdc, Figure 16)	$I_{RM(REC)}$	—	1.5	2.0	Amp

*Indicates JEDEC Registered Data for 1N3909 Series.

FAST RECOVERY
POWER RECTIFIERS

50-600 VOLTS
30 AMPERES





*Dimension is a diameter.

All JEDEC dimensions and notes apply

CASE 257
DO-5

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed

FINISH: All external surfaces corrosion resistant and readily solderable

POLARITY: Cathode to Case

WEIGHT: 17 Grams (Approximately)

FIGURE 1 – FORWARD VOLTAGE

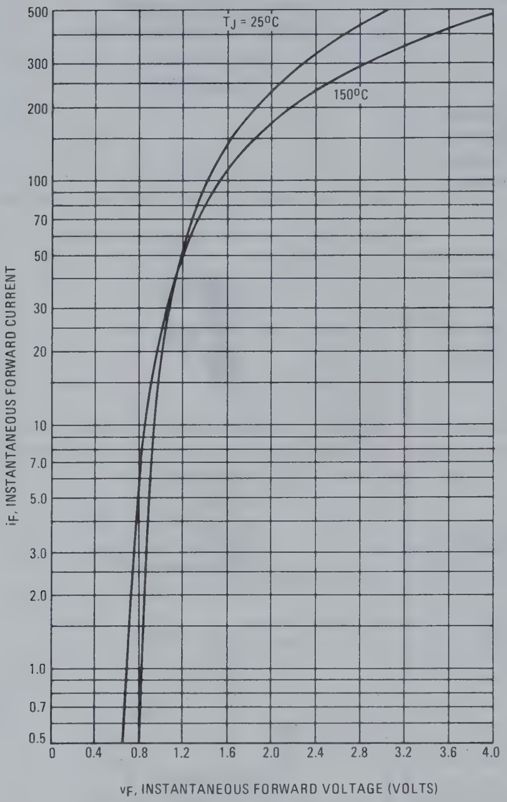
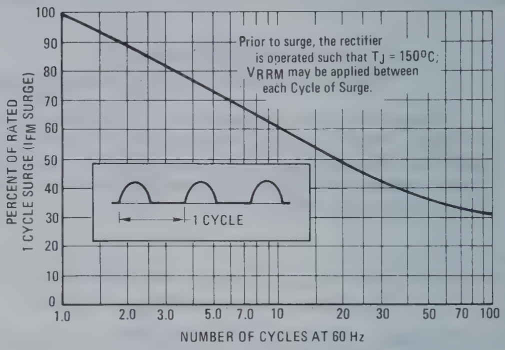
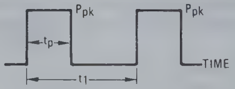


FIGURE 2 – MAXIMUM SURGE CAPABILITY



NOTE 1



DUTY CYCLE, D = t_p/t_1
PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the case should be measured using a thermocouple placed on the case at the temperature reference point (see Note 3). The thermal mass connected to the case is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_C, the junction temperature may be determined by:

$$T_J = T_C + \Delta T_{JC}$$

where ΔT_{JC} is the increase in junction temperature above the case temperature. It may be determined by:

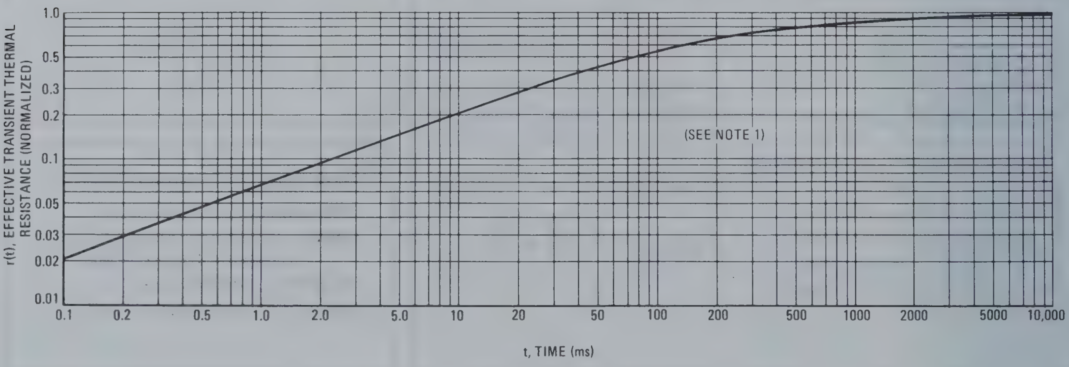
$$\Delta T_{JC} = P_{pk} \cdot R_{\theta JC} [D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) - r(t_1)]$$

where

$r(t)$ = normalized value of transient thermal resistance at time, t, from Figure 3, i.e.:

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

FIGURE 3 – THERMAL RESPONSE



SINE WAVE INPUT

FIGURE 4 — FORWARD POWER DISSIPATION

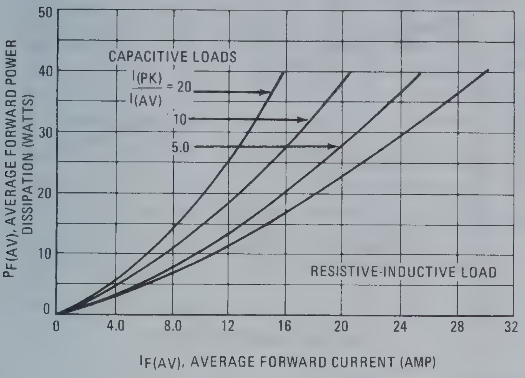


FIGURE 6 — CURRENT DERATING

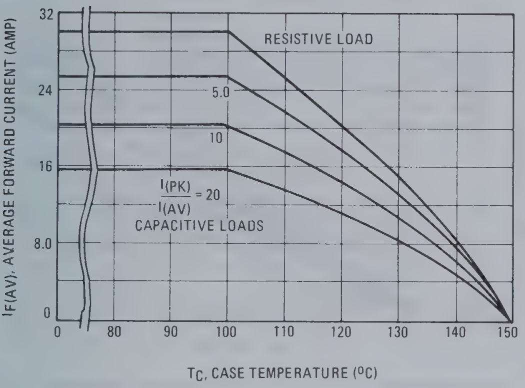
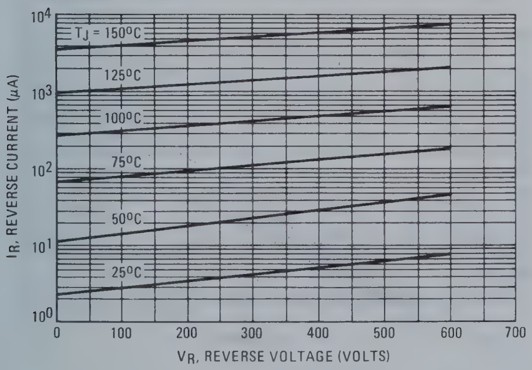


FIGURE 8 — TYPICAL REVERSE CURRENT



SQUARE WAVE INPUT

FIGURE 5 — FORWARD POWER DISSIPATION

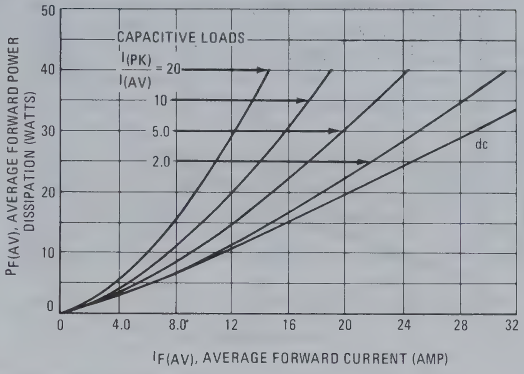


FIGURE 7 — CURRENT DERATING

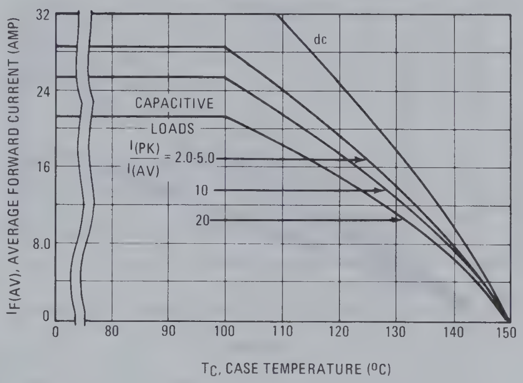
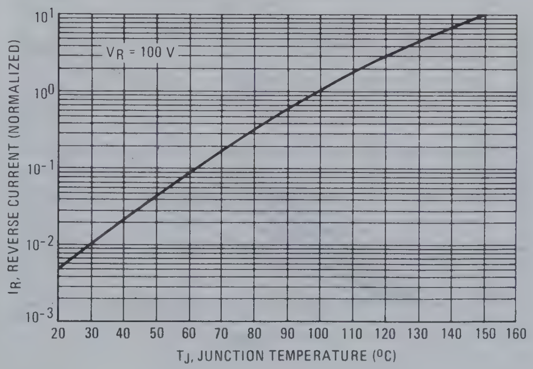


FIGURE 9 — NORMALIZED REVERSE CURRENT



TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 10 – FORWARD RECOVERY TIME

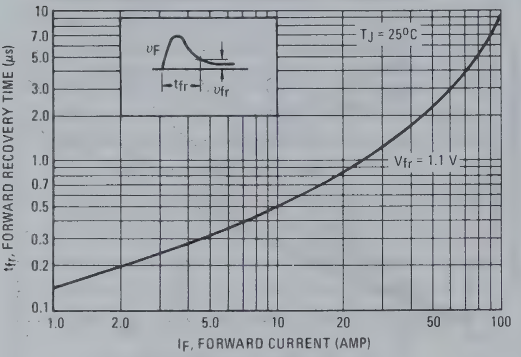
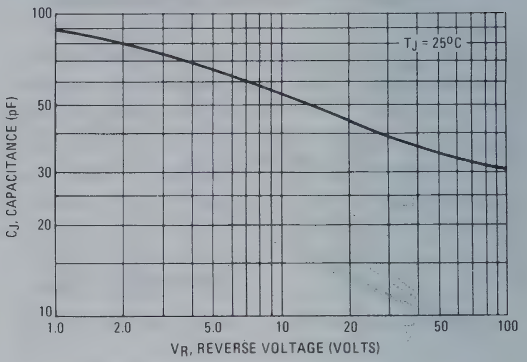


FIGURE 11 – JUNCTION CAPACITANCE



TYPICAL RECOVERED STORED CHARGE DATA

(See Note 2)

FIGURE 12 – T_J = 25°C

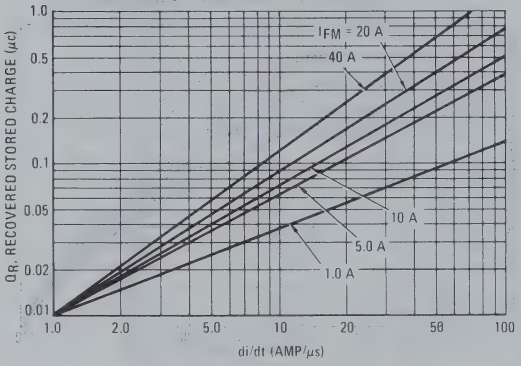


FIGURE 13 – T_J = 75°C

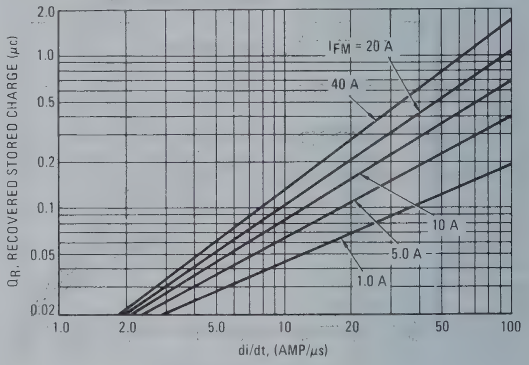


FIGURE 14 – T_J = 100°C

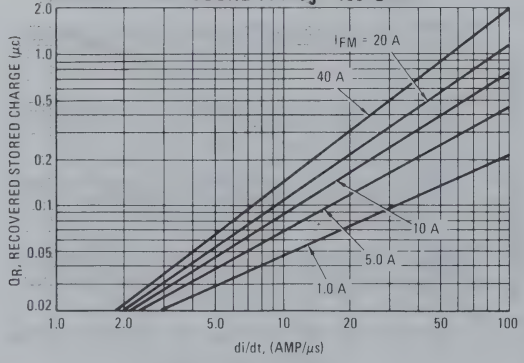


FIGURE 15 – T_J = 150°C

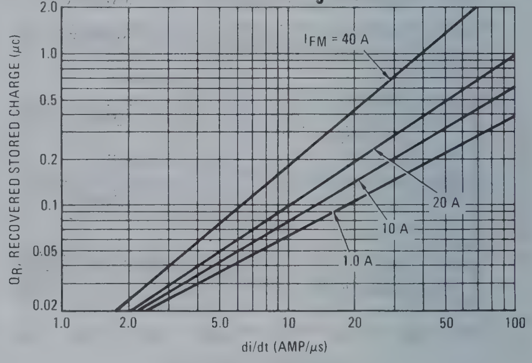
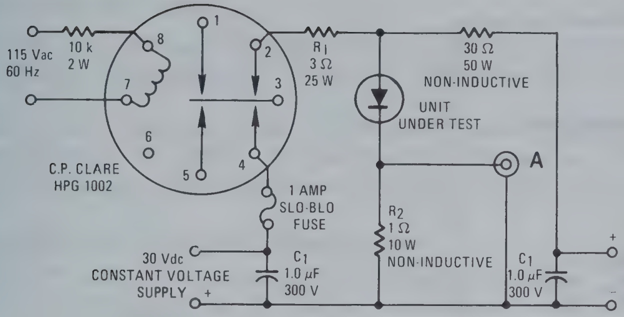


FIGURE 16 – REVERSE RECOVERY CIRCUIT


115 Vac
60 Hz
10 k
2 W
8
1
2
3
7
6
5
4
C.P. CLARE
HPG 1002
R1
3 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1 AMP
SLO-BLO
FUSE
30 Vdc
CONSTANT VOLTAGE
SUPPLY
C1
1.0 µF
300 V
R2
1 Ω
10 W
NON-INDUCTIVE
C1
1.0 µF
300 V
+
−

A – TEKTRONIX 545A, K PLUG IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 – ADJUSTED FOR 1.4 Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER INDUCTANCE ≈ 38 µH

R_2 – TEN-1 W, 10 Ω, 1% CARBON CORE IN PARALLEL

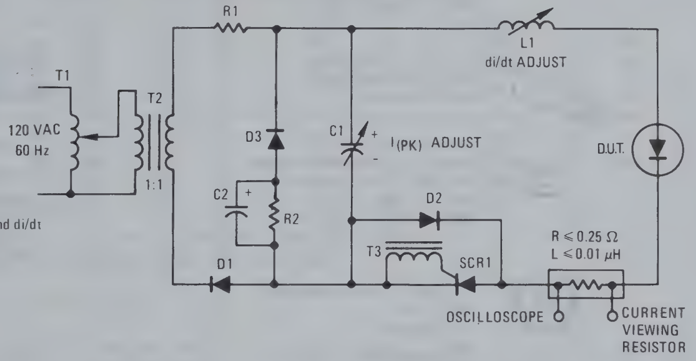
$T_A = 25\ ^{+10}_{-0}\ ^\circ C$ FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
Z_{out} = 1½ Ω MAX, DC to 2 kHz

FIGURE 17 – JEDEC REVERSE RECOVERY CIRCUIT

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4933
SCR1 = MCR729-10
C1 = 0.5 to 50 µF
C2 ≈ 4000 µF
L1 = 1.0 - 27 µH
T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)


R1
T1
120 VAC
60 Hz
T2
1:1
L1
di/dt ADJUST
D3
C1
+
-
I(PK) ADJUST
D.U.T.
C2
+
R2
D2
T3
SCR1
D1
R ≤ 0.25 Ω
L ≤ 0.01 µH
OSCILLOSCOPE
CURRENT
VIEWING
RESISTOR

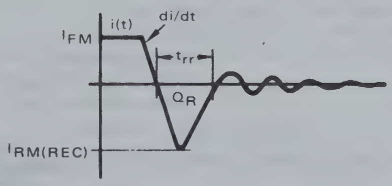
NOTE 2

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using I_F = 1.0 A, V_R = 30 V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.

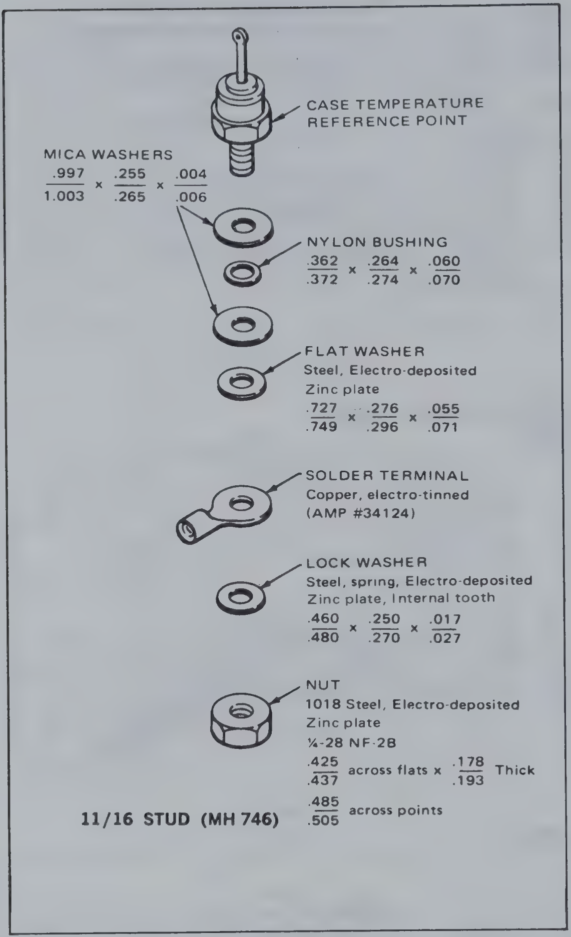

di/dt
i(t)
I_{FM}
t_{rr}
Q_R
$I_{RM(REC)}$

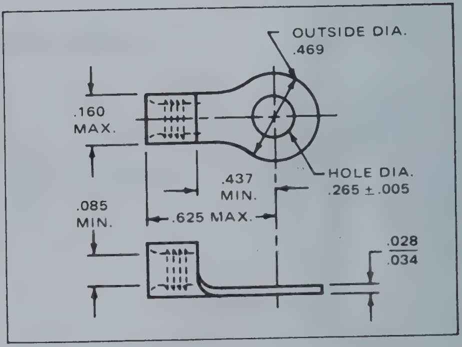
From stored charge curves versus di/dt, recovery time (t_{rr}) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

INSULATING HARDWARE KIT AVAILABLE UPON REQUEST


CASE TEMPERATURE REFERENCE POINT
MICA WASHERS
.997/1.003 x .255/.265 x .004/.006
NYLON BUSHING
.362/.372 x .264/.274 x .060/.070
FLAT WASHER
Steel, Electro-deposited Zinc plate
.727/.749 x .276/.296 x .055/.071
SOLDER TERMINAL
Copper, electro-tinned
(AMP #34124)
LOCK WASHER
Steel, spring, Electro-deposited Zinc plate, Internal tooth
.460/.480 x .250/.270 x .017/.027
NUT
1018 Steel, Electro-deposited Zinc plate
¼-28 NF-28
.425/.437 across flats x .178/.193 Thick
.485/.505 across points
11/16 STUD (MH 746)

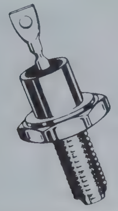

OUTSIDE DIA. .469
.160 MAX.
HOLE DIA. .265 ± .005
.437 MIN.
.085 MIN.
.625 MAX.
.028/.034

CASE TO HEAT SINK THERMAL RESISTANCE UNDER VARIOUS CONDITIONS

Metal-to-Metal		Mica Insulation	
Dry	Lubrication	Dry	Lubrication
0.38	0.20	0.89	0.70

TORQUE: 25 IN-LBS

1N3993 thru 1N4000 (ZENER DIODES)



CASE 56
(DO-4)

Low-voltage, alloy-junction zener diodes in hermetically sealed package with cathode connected to case. Supplied with mounting hardware.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 10 Watts. (Derate 83.3 mW/°C above 55°C).

The type numbers shown in the table have a standard tolerance on the nominal zener voltage of ±10%. A standard tolerance of ±5% on individual units is also available and is indicated by suffixing "A" to the standard type number.

ELECTRICAL CHARACTERISTICS

($T_B = 30°C \pm 3$, $V_F = 1.5$ max @ $I_F = 2$ amp for all units)

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance		Max DC Zener Current I_{ZM} mA	Reverse Leakage Current	
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} = 1.0 mA Ohms		I_R μA	V_R Volts
1N3993	3.9	640	2.0	400	2380	100	0.5
1N3994	4.3	580	1.5	400	2130	100	0.5
1N3995	4.7	530	1.2	500	1940	50	1.0
1N3996	5.1	490	1.1	550	1780	10	1.0
1N3997	5.6	445	1.0	600	1620	10	1.0
1N3998	6.2	405	1.1	750	1460	10	2.0
1N3999	6.8	370	1.2	500	1330	10	2.0
1N4000	7.5	335	1.3	250	1210	10	3.0

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES:

To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±3%, ±2%, ±1%), the Motorola type number should be used.

10	M	5.0	A	Z	3
Device Description	Motorola	Nominal Voltage	Alloy	Zener Diode	Tolerance (±%)

Example: 10M5.0AZ3

(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±2.0%, ±1.0%).

Zener diodes can be obtained in sets consisting of two or more matched devices. The method for specifying such matched sets is similar to the one described in (A) for specifying units with a special voltage and/or tolerance except that two extra suffixes are added to the code number described.

These units are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set being ordered.

10	M	5.1	A	Z	5	B	1
Device Description	Motorola	5.1 Volts (each device)	Alloy	Zener Diodes	Tolerance per device (±5%) (omit for ±20% units)	Code* (A-Not used)	Overall Tolerance of set (±1%)

*Code:
B – Two devices in series
C – Three devices in series
D – Four devices in series

Example: 10M5.1AZ5B1

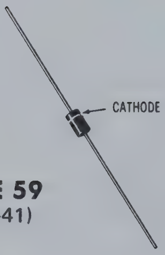
(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:

10	M	4.7	A	Z	Z	10
Device Description	Motorola	Nominal Voltage	Alloy	Zener Diodes	Clipper	Tolerance for each of the two Zener voltages (not a matching requirement)

Example: 10M4.7AZZ10

1N4001 thru 1N4007



CASE 59
(DO-41)

Surmetic rectifiers, subminiature size, axial lead mounted rectifiers for general purpose low-power applications.

MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	400	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz peak)	$V_{RM(non-rep)}$	75	150	300	600	900	1200	1500	Volts
RMS Reverse Voltage	V_r	35	70	140	280	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 6, $T_A = 75°C$)	I_O	1.0							Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions, see Figure 2)	$I_{FM(surge)}$	30 (for 1 cycle)							Amp
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175							°C

ELECTRICAL CHARACTERISTICS

Characteristic and Conditions	Symbol	Max	Unit
Maximum Instantaneous Forward Voltage Drop ($i_F = 1.0$ Amp, $T_J = 25°C$) Figure 1	V_F	1.1	Volts
Maximum Full-Cycle Average Forward Voltage Drop ($I_O = 1.0$ Amp, $T_L = 75°C$, 1 inch leads)	$V_{F(AV)}$	0.8	Volts
Maximum Reverse Current (rated dc voltage) $T_J = 25°C$ $T_J = 100°C$	I_R	0.01 0.05	mA
Maximum Full-Cycle Average Reverse Current ($I_O = 1.0$ Amp, $T_L = 75°C$, 1 inch leads)	$I_{R(AV)}$	0.03	mA

MECHANICAL CHARACTERISTICS

CASE: Void free, Transfer Molded

MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 350°C, ⅜″ from case for 10 seconds at 5 lbs. tension

FINISH: All external surfaces are corrosion-resistant, leads are readily solderable

POLARITY: Cathode indicated by color band

WEIGHT: 0.40 Grams (approximately)

FIGURE 1 — FORWARD VOLTAGE

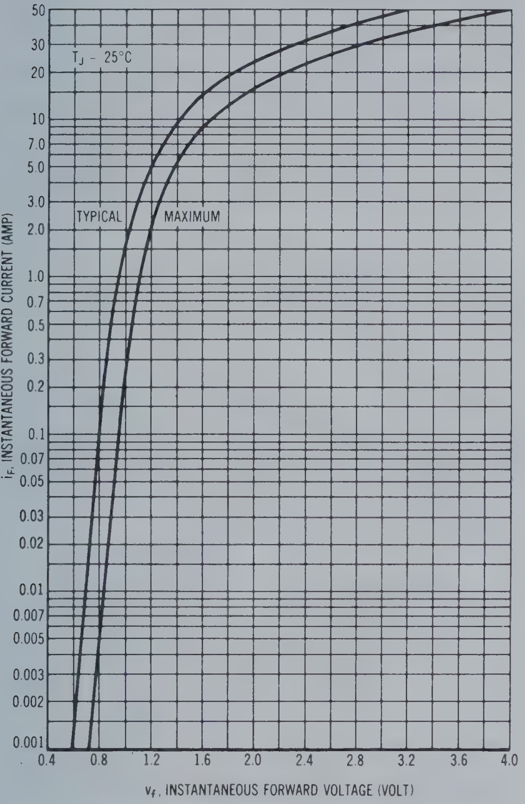


FIGURE 2 — MAXIMUM SURGE CAPABILITY

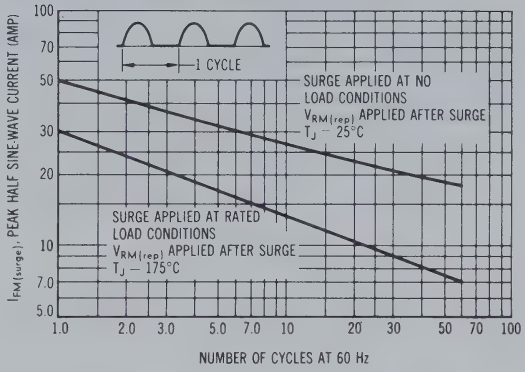


FIGURE 3 — FORWARD VOLTAGE TEMPERATURE COEFFICIENT

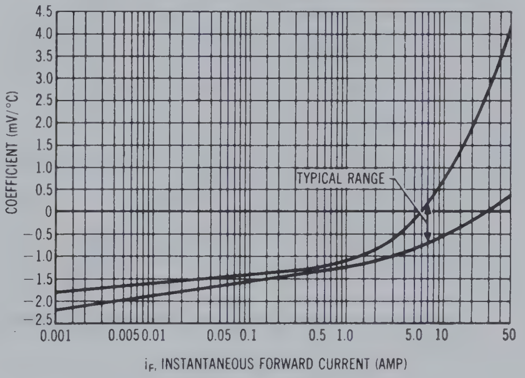
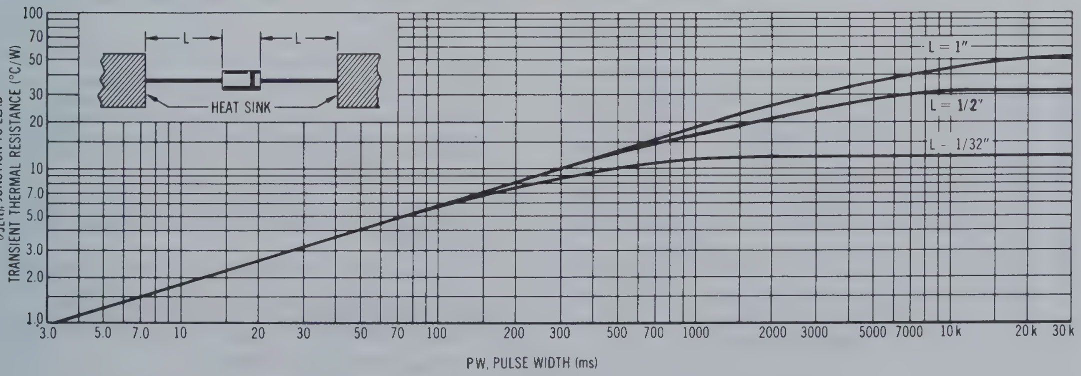


FIGURE 4 — TYPICAL TRANSIENT THERMAL RESISTANCE



FOR $\theta_{JL(t)}$ VALUES AT PULSE WIDTHS LESS THAN 3.0 ms, THE ABOVE CURVE CAN BE EXTRAPOLATED DOWN TO 10 μs AT A CONTINUING SLOPE OF 1/2

CURRENT DERATING DATA

FIGURE 5 — LEAD TEMPERATURE DERATING (DC ONLY)

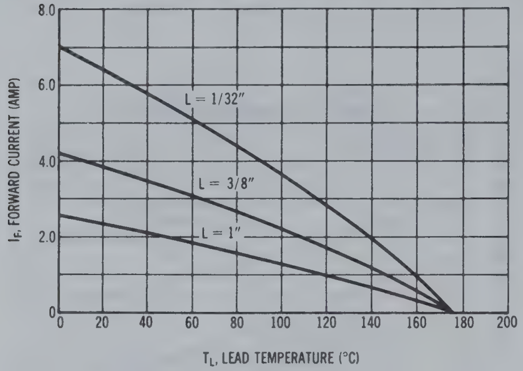


FIGURE 6 — RESISTIVE, INDUCTIVE LOADS

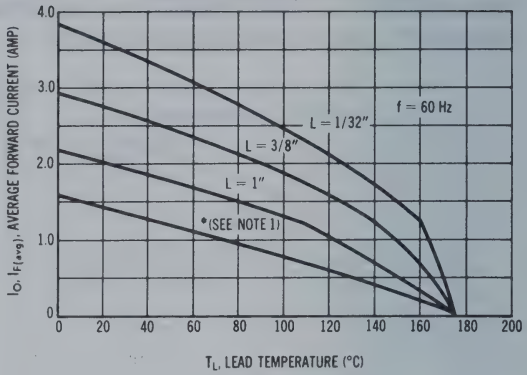


FIGURE 7 — CAPACITIVE LOADS

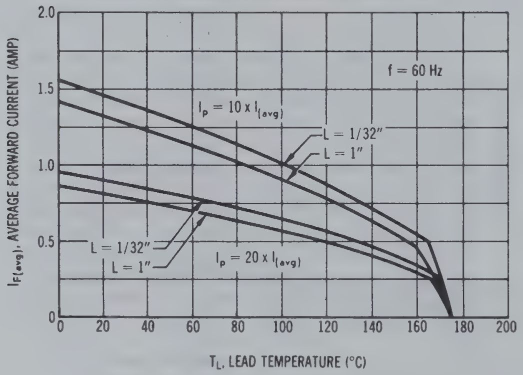
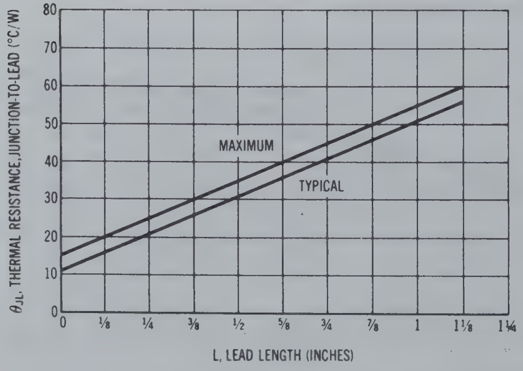


FIGURE 8 — STEADY-STATE THERMAL RESISTANCE

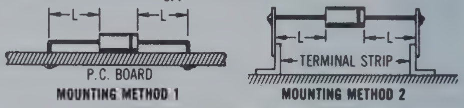


NOTES

NOTE 1

Data shown for thermal resistance junction-to-ambient (θ_{JA}) for the mountings shown is to be used as typical guideline values for preliminary engineering or in case the tie point temperature cannot be measured.

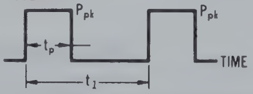
TYPICAL VALUES FOR θ_{JA} IN STILL AIR



MOUNTING METHOD	LEAD LENGTH, L (IN.)			θ_{JA}
	1/32	3/8	1	
1	—	75	85	°C/W
2	55	72	85	°C/W

***Using Mounting Method 1 or 2 with L = 1″ the curve marked * in Figure 6 can be used for 60 Hz half-wave resistive/inductive load (Rating vs. Ambient Temperature). The abscissa of Figure 6 then indicates T_A in °C.**

NOTE 2



DUTY CYCLE, $D = t_p/t_1$

PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the lead should be measured using a thermocouple placed on the lead as close as possible to the tie point. The thermal mass connected to the tie point is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_L, the junction temperature may be determined by:

$$T_J = T_L + \triangle T_{JL},$$

where $\triangle T_{JL}$ is the increase in junction temperature above the lead temperature. It may be determined by:

$$\triangle T_{JL} = P_{pk}\left[\theta_{JL(\infty)} \cdot D + (1 - D) \cdot \theta_{JL(t_1+t_p)} + \theta_{JL(t_p)} - \theta_{JL(t_1)}\right]$$

where $\theta_{JL(t)}$ = value of transient thermal resistance at time t, i.e.:

$\theta_{JL(t_1+t_p)}$ = value of $\theta_{JL(t)}$ at time t_1+t_p

$\theta_{JL(t_p)}$ = value of $\theta_{JL(t)}$ at end of pulse width t_p

$\theta_{JL(t_1)}$ = value of $\theta_{JL(t)}$ at time t_1

TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 9 — FORWARD RECOVERY TIME

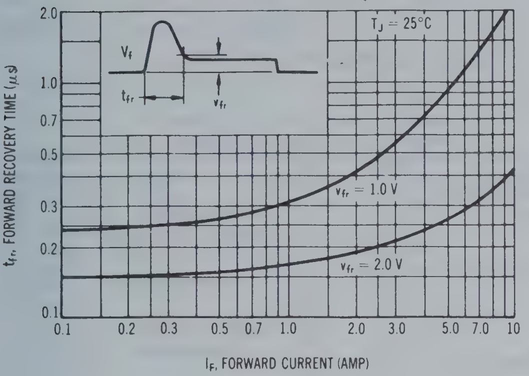


FIGURE 10 — REVERSE RECOVERY TIME

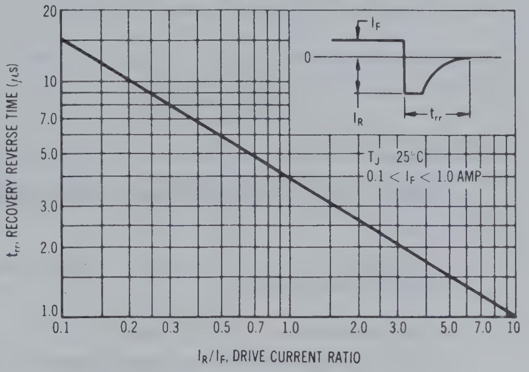


FIGURE 11 — RECTIFICATION WAVEFORM EFFICIENCY

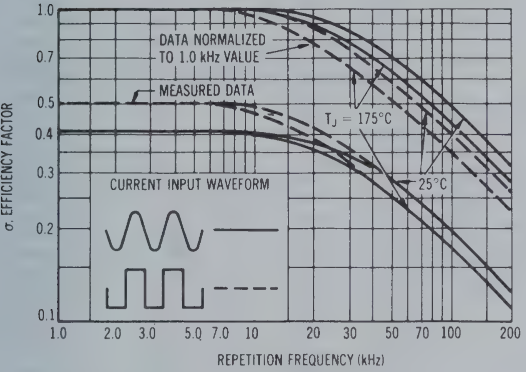
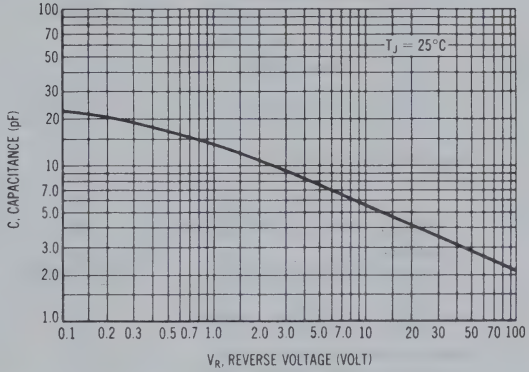
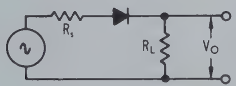


FIGURE 12 — JUNCTION CAPACITANCE



RECTIFIER EFFICIENCY NOTE

FIGURE 13 — SINGLE-PHASE HALF-WAVE RECTIFIER CIRCUIT



The rectification efficiency factor σ shown in Figure 11 was calculated using the formula:

$$\sigma = \frac{P_{dc}}{P_{rms}} = \frac{\dfrac{V^2_O(dc)}{R_L}}{\dfrac{V^2_O(rms)}{R_L}} \cdot 100\% = \frac{V^2_O(dc)}{V^2_O(ac) + V^2_O(dc)} \cdot 100\% \quad (1)$$

For a sine wave input $V_m \sin(\omega t)$ to the diode, assumed lossless, the maximum theoretical efficiency factor becomes:

$$\sigma(\text{sine}) = \frac{\dfrac{V^2_m}{\pi^2 R_L}}{\dfrac{V^2_m}{4R_L}} \cdot 100\% = \frac{4}{\pi^2} \cdot 100\% = 40.6\% \quad (2)$$

For a square wave input of amplitude V_m, the efficiency factor becomes:

$$\sigma(\text{square}) = \frac{\dfrac{V^2_m}{2R_L}}{\dfrac{V^2_m}{R_L}} \cdot 100\% = 50\% \quad (3)$$

(A full wave circuit has twice these efficiencies)

As the frequency of the input signal is increased, the reverse recovery time of the diode (Figure 10) becomes significant, resulting in an increasing ac voltage component across R_L which is opposite in polarity to the forward current, thereby reducing the value of the efficiency factor σ, as shown on Figure 11.

It should be emphasized that **Figure 11 shows waveform efficiency only; it does not provide a measure of diode losses.** Data was obtained by measuring the ac component of V_O with a true rms ac voltmeter and the dc component with a dc voltmeter. The data was used in Equation 1 to obtain points for Figure 11.

1N4057,A thru 1N4085, A

For Specifications, See 1N429 Data.

1N4099 thru 1N4135 (SILICON)
(MZ4614 thru MZ4627) *

LOW-LEVEL SILICON PASSIVATED ZENER DIODES

. . . designed for 250 mW applications requiring low leakage, low impedance, and low noise.

- Voltage Range from 1.8 to 100 Volts
- First Zener Diode Series to Specify Noise–50% Lower than Conventional Diffused Zeners
- Zener Impedance and Zener Voltage Specified for Low-Level Operation at I_{ZT} = 250 μA
- Low Leakage Current –
  I_R from 0.01 to 10 μA over Voltage Range
- Expanded Temperature Range –
  T_J = -65 to +200°C

SILICON
ZENER DIODES

(±5.0% TOLERANCE)

250 MILLIWATTS
1.8–100 VOLTS

SILICON OXIDE
PASSIVATED JUNCTION

MAXIMUM RATINGS

Rating	Value	Unit
DC Power Dissipation, 25°C Ambient	250	mW
Derating Factor	1.43	mW/°C
Junction and Storage Temperature	-65 to +200	°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass.

DIMENSIONS: See outline drawing.

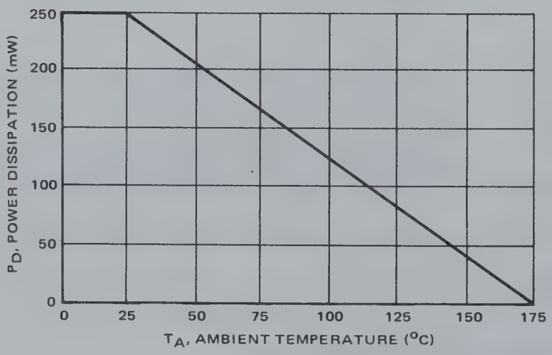
FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

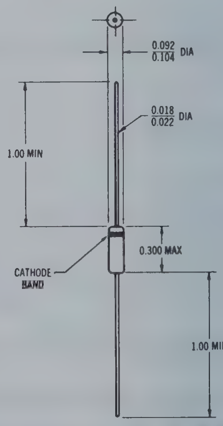
POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 gram (approx)

MOUNTING POSITION: Any

POWER TEMPERATURE DERATING CURVE





CASE 51
(DO-7)

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*Identical to 1N4614 registration, except registration has a minimum package diameter of 0.115 inches.

ELECTRICAL CHARACTERISTICS

(T_A = 25°C unless otherwise noted) I_{ZT} = 250 µA and V_F = 1.0 V max @ I_F = 200 mA on all Types

Type Number (Note 1)	Nominal Zener Voltage V_Z (Note 1) (Volts)	Max Zener Impedance Z_{ZT} (Note 2) (Ohms)	Max Reverse Current I_R (µA) @ (Note 4)	Test Voltage V_R (Volts)	Max Noise Density At I_{ZT} = 250 µA N_D (Fig 1) (micro-volts per Square Root Cycle)	Max Zener Current I_{ZM} (Note 3) (mA)
MZ4614	1.8	1200	7.5	1.0	1.0	120
MZ4615	2.0	1250	5.0	1.0	1.0	110
MZ4616	2.2	1300	4.0	1.0	1.0	100
MZ4617	2.4	1400	2.0	1.0	1.0	95
MZ4618	2.7	1500	1.0	1.0	1.0	90
MZ4619	3.0	1600	0.8	1.0	1.0	85
MZ4620	3.3	1650	7.5	1.5	1.0	80
MZ4621	3.6	1700	7.5	2.0	1.0	75
MZ4622	3.9	1650	5.0	2.0	1.0	70
MZ4623	4.3	1600	4.0	2.0	1.0	65
MZ4624	4.7	1550	10	3.0	1.0	60
MZ4625	5.1	1500	10	3.0	2.0	55
MZ4626	5.6	1400	10	4.0	4.0	50
MZ4627	6.2	1200	10	5.0	5.0	45
1N4099	6.8	200	10	5.2	40	35
1N4100	7.5	200	10	5.7	40	31.8
1N4101	8.2	200	1.0	6.3	40	29.0
1N4102	8.7	200	1.0	6.7	40	27.4
1N4103	9.1	200	1.0	7.0	40	26.2
1N4104	10	200	1.0	7.6	40	24.8
1N4105	11	200	0.05	8.5	40	21.6
1N4106	12	200	0.05	9.2	40	20.4
1N4107	13	200	0.05	9.9	40	19.0
1N4108	14	200	0.05	10.7	40	17.5
1N4109	15	100	0.05	11.4	40	16.3
1N4110	16	100	0.05	12.2	40	15.4
1N4111	17	100	0.05	13.0	40	14.5
1N4112	18	100	0.05	13.7	40	13.2
1N4113	19	150	0.05	14.5	40	12.5
1N4114	20	150	0.01	15.2	40	11.9
1N4115	22	150	0.01	16.8	40	10.8
1N4116	24	150	0.01	18.3	40	9.9
1N4117	25	150	0.01	19.0	40	9.5
1N4118	27	150	0.01	20.5	40	8.8
1N4119	28	200	0.01	21.3	40	8.5
1N4120	30	200	0.01	22.8	40	7.9
1N4121	33	200	0.01	25.1	40	7.2
1N4122	36	200	0.01	27.4	40	6.6
1N4123	39	200	0.01	29.7	40	6.1
1N4124	43	250	0.01	32.7	40	5.5
1N4125	47	250	0.01	35.8	40	5.1
1N4126	51	300	0.01	38.8	40	4.6
1N4127	56	300	0.01	42.6	40	4.2
1N4128	60	400	0.01	45.6	40	4.0
1N4129	62	500	0.01	47.1	40	3.8
1N4130	68	700	0.01	51.7	40	3.5
1N4131	75	700	0.01	57.0	40	3.1
1N4132	82	800	0.01	62.4	40	2.9
1N4133	87	1000	0.01	66.2	40	2.7
1N4134	91	1200	0.01	69.2	40	2.6
1N4135	100	1500	0.01	76.0	40	2.3

NOTE 1: TOLERANCE AND VOLTAGE DESIGNATION

The type numbers shown have a standard tolerance of ±5.0% on the nominal zener voltage.

NOTE 2: ZENER IMPEDANCE (Z_{ZT}) DERIVATION

The zener impedance is derived from the 60 cycle ac voltage, which results when an ac current having an rms value equal to 10% of the dc zener current (I_{ZT}) is superimposed on I_{ZT}.

NOTE 3: MAXIMUM ZENER CURRENT RATINGS (I_{ZM})

Maximum zener current ratings are based on maximum zener voltage of the individual units.

NOTE 4: REVERSE LEAKAGE CURRENT I_R

Reverse leakage currents are guaranteed and are measured at V_R as shown on the table.

ZENER NOISE DENSITY

A zener diode generates noise when it is biased in the zener direction. A small part of this noise is due to the internal resistance associated with the device. A larger part of zener noise is a result of the zener breakdown phenomenon and is called microplasma noise. This microplasma noise is generally considered "white" noise with equal amplitude for all frequencies from about zero cycles to approximately 200,000 cycles. To eliminate the higher frequency components of noise a small shunting capacitor can be used. The lower frequency noise generally must be tolerated since a capacitor required to eliminate the lower frequencies would degrade the regulation properties of the zener in many applications.

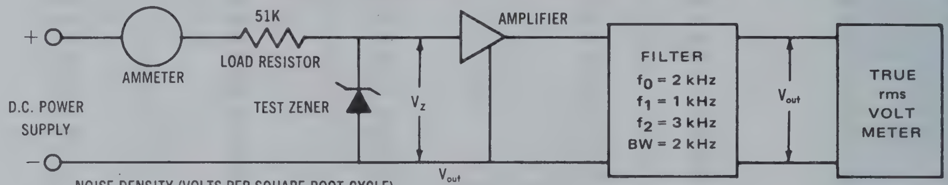
Motorola is rating this series with a maximum noise density at 250 microamperes. The rating of microvolts RMS per square root cycle enables calculation of the maximum RMS noise for any bandwidth.

Noise density decreases as zener current increases. This can be seen by the graph in Figure 2 where a typical noise density is plotted as a function of zener current.

The junction temperature will also change the zener noise levels. Thus the noise rating must indicate bandwidth, current level and temperature.

The block diagram given in Figure 1 shows the method used to measure noise density. The input voltage and load resistance is high so that the zener is driven from a constant current source. The amplifier must be low noise so that the amplifier noise is negligible compared to the test zener. The filter bandpass is known so that the noise density in volts RMS per square root cycle can be calculated.

FIGURE 1 – NOISE DENSITY MEASUREMENT METHOD



$$\text{NOISE DENSITY (VOLTS PER SQUARE ROOT CYCLE)} = \frac{V_{out}}{\text{OVERALL GAIN} \sqrt{BW}}$$

WHERE: BW = FILTER BANDWIDTH (CYCLES)

V_{out} = OUTPUT NOISE (VOLTS RMS)

FIGURE 2 – TYPICAL NOISE DENSITY versus ZENER CURRENT

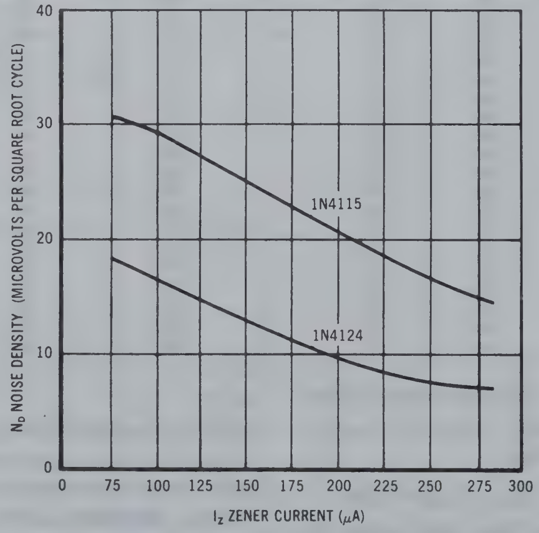


FIGURE 3 – TYPICAL CAPACITANCE

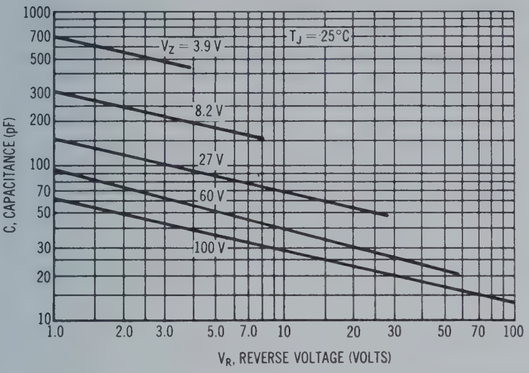
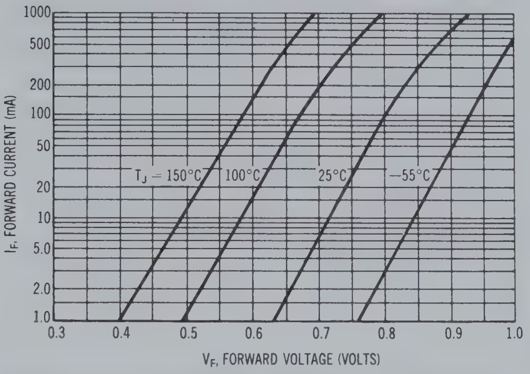


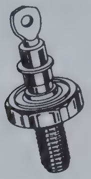
FIGURE 4 – TYPICAL FORWARD CHARACTERISTICS



1N4370 thru 1N4372
1N4370A thru 1N4372A

For Specifications, see 1N746 Data.

1N4387 (SILICON)
(MV1804)



CASE 44
(DO-4)

cathode connected to stud

Silicon varactor diode for high-power frequency multiplication applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	150	Vdc
RF Power Input	P_{in}	40	Watts
Total Device Dissipation @ $T_C = 75°C$ Derate above 75° C	P_D	20 200	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

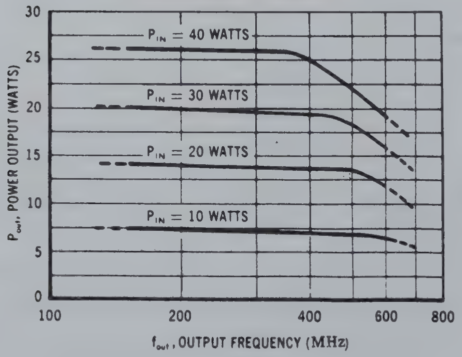
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage ($I_R = 10\ \mu$Adc)	BV_R	150	200	-	Vdc
Series Resistance (V_R = 6.0 Vdc, f = 50 MHz)	R_S	-	1.0	1.5	Ohms
Junction Capacitance * (V_R = 6.0 Vdc, f = 1.0 MHz)	C_T	-	25	35	pF
Figure of Merit (V_R = 10 Vdc, f = 50 MHz)	Q	150	200	-	-

FUNCTIONAL TESTS

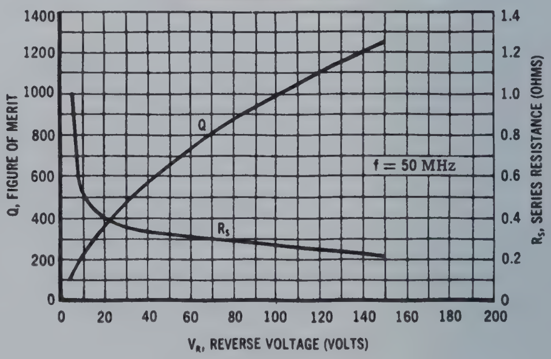
Power Output	Tripler Circuit P_{in} = 30 W, f_{in} = 150 MHz, f_{out} = 450 MHz	P_{out}	15	18	-	Watts
Efficiency		η	50	60	-	%

$^*C_T = C_J + C_C$

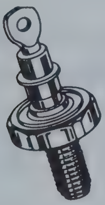
POWER OUTPUT versus OUTPUT FREQUENCY FOR HARMONIC TRIPLING



SERIES RESISTANCE AND FIGURE OF MERIT versus REVERSE VOLTAGE



1N4388 (SILICON)
(MV1806)



Silicon varactor diode for high-frequency harmonic generation applications.

cathode connected to stud

CASE 44
(DO-4)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	100	Vdc
Forward Current	I_F	1.0	Amp
RF Power Input	P_{in}	25	Watts
Total Device Dissipation @ $T_C = 75°C$ Derate above 75° C	P_D	10 0.10	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

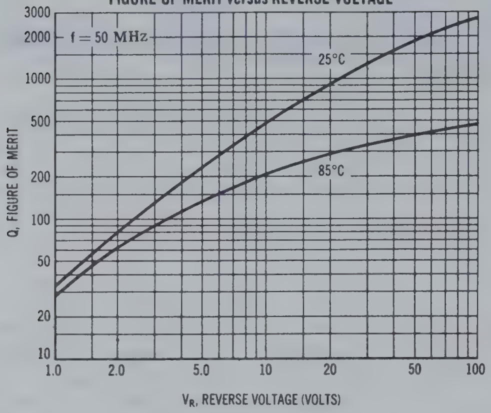
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage ($I_R = 10\ \mu$Adc)	BV_R	100	150	-	Vdc
Reverse Current	I_R				μAdc
(V_R = 75 Vdc)		-	0.5	2.0	
(V_R = 75 Vdc, T_A = 150° C)		-	-	100	
Diode Capacitance	C_T*				pF
(V_R = 6.0 Vdc, f = 1.0 MHz)		-	10	20	
(V_R = 90 Vdc, f = 1.0 MHz)		-	5.0	10	
Series Resistance (V_R = 6.0 Vdc, f = 50 MHz)	R_S	-	1.2	2.0	Ohms
Figure of Merit	Q				-
(V_R = 10 Vdc, f = 50 MHz)		200	300	-	
(V_R = 90 Vdc, f = 50 MHz)		1000	-	-	

FUNCTIONAL TESTS

Power Output	**Doubler Circuit** (Figure 1) P_{in} = 20 W, f_{in} = 500 MHz, f_{out} = 1000 MHz	P_{out}	11.0	12.0	-	Watts
Efficiency		η	55	60	-	%

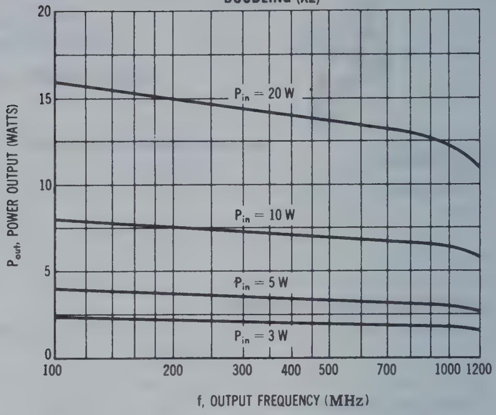
$*C_T = C_J + C_C$

FIGURE OF MERIT versus REVERSE VOLTAGE

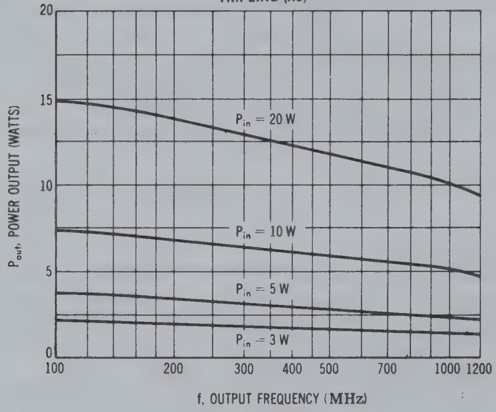


POWER OUTPUT versus OUTPUT FREQUENCY

DOUBLING (X2)



TRIPLING (X3)



QUADRUPLING (X4)

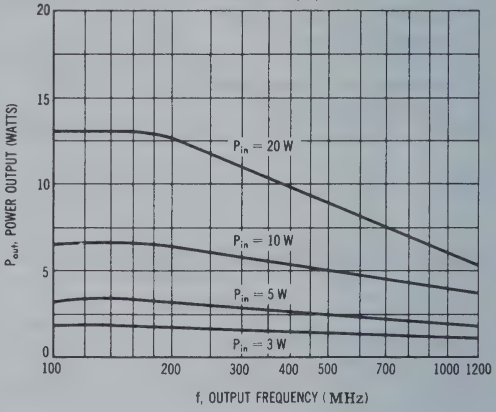
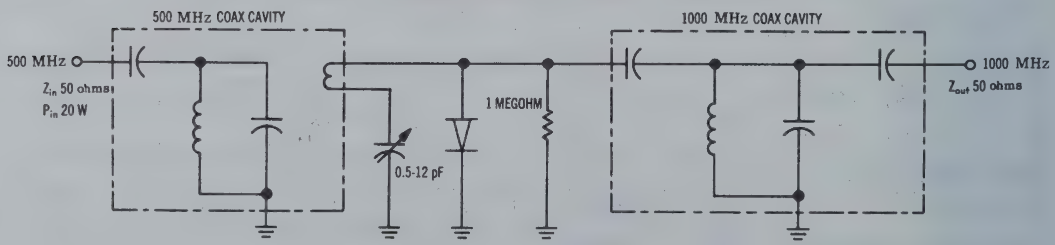


FIGURE 1 — HARMONIC DOUBLER EFFICIENCY TEST CIRCUIT


500 MHz COAX CAVITY
1000 MHz COAX CAVITY
500 MHz
Z_{in} 50 ohms
P_{in} 20 W
1 MEGOHM
0.5-12 pF
1000 MHz
Z_{out} 50 ohms

1N4549 thru 1N4556
1N4557 thru 1N4564

For Specifications, See IN2804 Data

1N4565-1N4584

1N4775-1N4784

1N4765-1N4774

Low level temperature-compensated zener reference diodes—highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction and Storage Temperature: –65°C to +175°C

DC Power Dissipation: 400 Milliwatts at 50°C Ambient
(Derate 3.2 mW/°C Above 50°C)

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

1N4565-1N4584/1N4775-1N4784/1N4765-1N4774 (continued)

TYPE	ΔV_Z (Note 1)	@ Test Temperature	Temperature Coefficient for Reference	Dynamic Imped. Ohms
	Volts Max	°C	%/°C (Note 1)	Max (Note 2)
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4565	0.048	0, +25, +75	0.01	200
1N4566	0.024		0.005	
1N4567	0.010		0.002	
1N4568	0.005		0.001	
1N4569	0.002		0.0005	
1N4565A	0.099	−55, 0, +25, +75, +100	0.01	200
1N4566A	0.050		0.005	
1N4567A	0.020		0.002	
1N4568A	0.010		0.001	
1N4569A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4570	0.048	0, +25, +75	0.01	100
1N4571	0.024		0.005	
1N4572	0.010		0.002	
1N4573	0.005		0.001	
1N4574	0.002		0.0005	
1N4570A	0.099	−55, 0, +25, +75, +100	0.01	100
1N4571A	0.050		0.005	
1N4572A	0.020		0.002	
1N4573A	0.010		0.001	
1N4574A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 2.0$ mA)				
1N4575	0.048	0, +25, +75	0.01	50
1N4576	0.024		0.005	
1N4577	0.010		0.002	
1N4578	0.005		0.001	
1N4579	0.002		0.0005	
1N4575A	0.099	−55, 0, +25, +75, +100	0.01	50
1N4576A	0.050		0.005	
1N4577A	0.020		0.002	
1N4578A	0.010		0.001	
1N4579A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 4.0$ mA)				
1N4580	0.048	0, +25, +75	0.01	25
1N4581	0.024		0.005	
1N4582	0.010		0.002	
1N4583	0.005		0.001	
1N4584	0.002		0.0005	
1N4580A	0.099	−55, 0, +25, +75, +100	0.01	25
1N4581A	0.050		0.005	
1N4582A	0.020		0.002	
1N4583A	0.010		0.001	
1N4584A	0.005		0.0005	

TYPE	ΔV_Z (Note 1)	@ Test Temperature	Temperature Coefficient for Reference	Dynamic Imped. Ohms
	Volts Max	°C	%/°C (Note 1)	Max (Note 2)
$V_Z = 8.5$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4775	0.064	0, +25, +75	0.01	200
1N4776	0.032		0.005	
1N4777	0.013		0.002	
1N4778	0.006		0.001	
1N4779	0.003		0.0005	
1N4775A	0.132	−55, 0, +25, +75, +100	0.01	200
1N4776A	0.066		0.005	
1N4777A	0.026		0.002	
1N4778A	0.013		0.001	
1N4779A	0.007		0.0005	
$V_Z = 8.5$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4780	0.064	0, +25, +75	0.01	100
1N4781	0.032		0.005	
1N4782	0.013		0.002	
1N4783	0.006		0.001	
1N4784	0.003		0.0005	
1N4780A	0.132	−55, 0, +25, +75, +100	0.01	100
1N4781A	0.066		0.005	
1N4782A	0.026		0.002	
1N4783A	0.013		0.001	
1N4784A	0.007		0.0005	
$V_Z = 9.1$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4765	0.068	0, +25, +75	0.01	350
1N4766	0.034		0.005	
1N4767	0.014		0.002	
1N4768	0.007		0.001	
1N4769	0.003		0.0005	
1N4765A	0.141	−55, 0, +25, +75, +100	0.01	350
1N4766A	0.070		0.005	
1N4767A	0.028		0.002	
1N4768A	0.014		0.001	
1N4769A	0.007		0.0005	
$V_Z = 9.1$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4770	0.068	0, +25, +75	0.01	200
1N4771	0.034		0.005	
1N4772	0.014		0.002	
1N4773	0.007		0.001	
1N4774	0.003		0.0005	
1N4770A	0.141	−55, 0, +25, +75, +100	0.01	200
1N4771A	0.070		0.005	
1N4772A	0.028		0.002	
1N4773A	0.014		0.001	
1N4774A	0.007		0.0005	

NOTE 1:

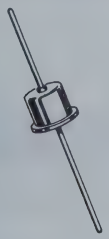
Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

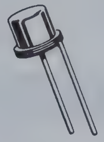
NOTE 2:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

1N4719 thru 1N4725 (SILICON)
1N4997 thru 1N5003
MR1030 thru MR1036, MR1038, MR1040



CASE 60
1N4719 THRU 1N4725
MR1030A THRU MR1040A



CASE 70
1N4997 thru 1N5003
MR1030B THRU MR1040B

Silicon high-conductance rectifiers available in either axial-lead or single-ended packages. Type numbers shown have cathode connected to case. For anode-to-case connection, add suffix "R" to type number, i. e. 1N4719R

MAXIMUM RATINGS (Both Package Types) $T_A = 25^oC$ unless otherwise noted

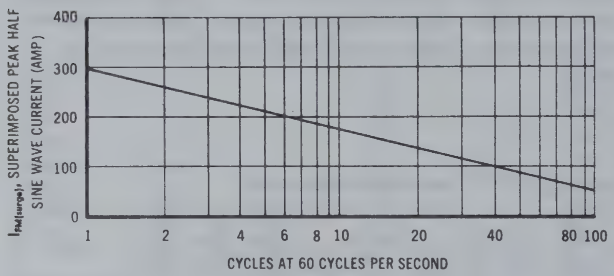
Rating	Symbol	1N 4719 MR 1030	1N 4720 MR 1031	1N 4721 MR 1032	MR 1033	1N 4722 MR 1034	MR 1035	1N 4723 MR 1036	1N 4724 MR 1038	1N 4725 MR 1040	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RM} (rep) V_{RM} (wkg) V_R	50	100	200	300	400	500	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	V_{RM} (non-rep)	100	200	300	400	500	600	720	1000	1200	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	350	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 cps, $T_A = 75^oC$) see figure 4	I_O	3.0									Amp
Peak Repetitive Forward Current ($T_A = 75^oC$)	I_{FM} (rep)	25									Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, $T_A = 75^oC$) see figure 1	I_{FM} (surge)	300 (for 1/2 cycle)									Amp
I^2t Rating (non-repetitive, 1 msec $<t<$ 8.3 msec)	I^2t	185									$A_{(rms)}{}^2s$
Operating and Case Temperature	T_J, T_{stg}	-65 to + 175									^oC
Thermal Resistance	θ_{JA}	30									^oC/Watt

1N4719 thru 1N4725 (Continued)

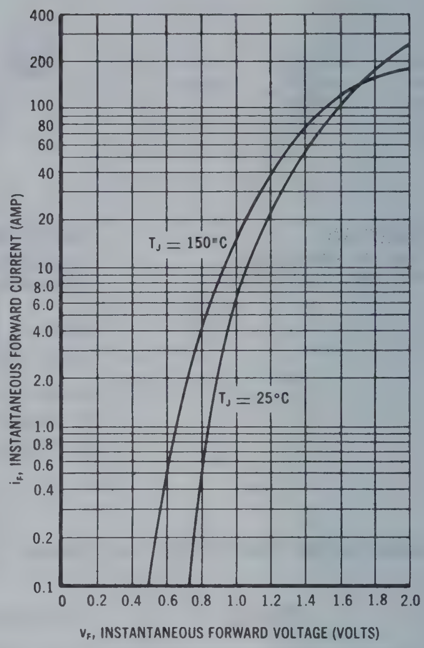
ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Max Limit	Unit
Full Cycle Average Forward Voltage Drop (I_O = 3.0 Amps and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$V_{F(AV)}$	0.45	Volts
DC Forward Voltage Drop (I_F = 3.0 Adc, T_A = 25°C)	V_F	0.9	Volts
Full Cycle Average Reverse Current (I_O = 3.0 Amps and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$I_{R(AV)}$	1.5	mA
DC Reverse Current (Rated V_R, T_A = 25°C)	I_R	0.5	mA

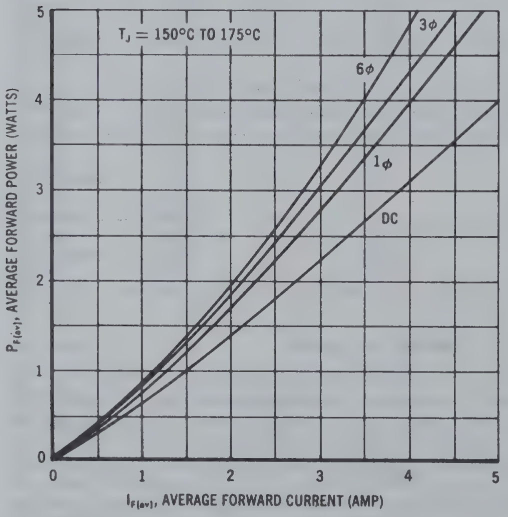
MAXIMUM SURGE CURRENT T_A = 75°C)



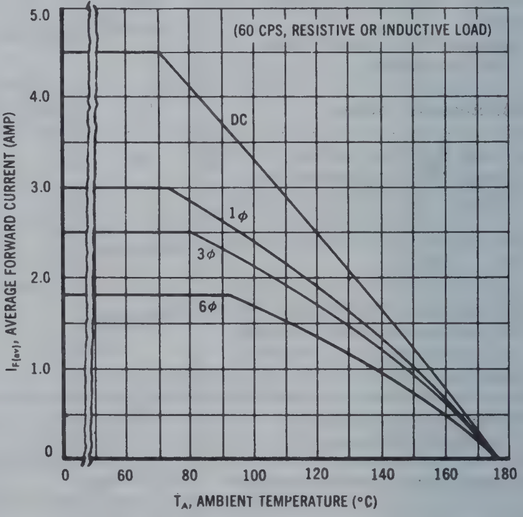
FORWARD VOLTAGE CHARACTERISTICS



MAXIMUM FORWARD POWER DISSIPATION versus AVERAGE FORWARD CURRENT



MAXIMUM FORWARD CURRENT versus AMBIENT TEMPERATURE



1N4728 thru 1N4764 (SILICON)
1M110ZS10 thru 1M200ZS10

Designers Data Sheet

1.0 WATT SURMETIC 30 SILICON ZENER DIODES

. . . a complete series of 1.0 Watt Zener Diodes with limits and operating characteristics that reflect the superior capabilities of silicon-oxide-passivated junctions. All this in an axial-lead, transfer-molded plastic package offering protection in all common environmental conditions.

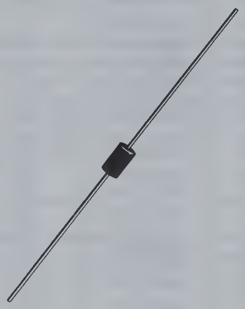
- To 80 Watts Surge Rating @ 1.0 ms
- Maximum Limits Guaranteed on Six Electrical Parameters
- Package No Larger Than the Conventional 400 mW Package

Designer's Data for "Worst Case" Conditions

The Designers Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

1.0 WATT
ZENER REGULATOR DIODES

3.3–200 VOLTS



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
*DC Power Dissipation @ $T_A = 50^oC$ Derate above 50^oC	P_D	1.0 6.67	Watt mW/^oC
DC Power Dissipation @ $T_L = 75^oC$ Lead Length = 3/8" Derate above 75^oC	P_D	3.0 24	Watts mW/^oC
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	^oC

MECHANICAL CHARACTERISTICS

CASE: Void-free, transfer-molded, thermosetting plastic

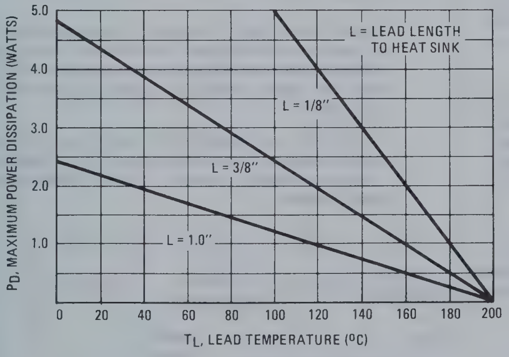
FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable

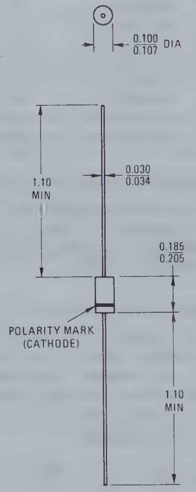
POLARITY: Cathode indicated by polarity band. When operated in zener mode, cathode will be positive with respect to anode

MOUNTING POSITION: Any

WEIGHT: 0.4 gram (approx)

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE





To convert inches to millimeters multiply by 25.4
All JEDEC dimensions and notes apply

CASE 59
DO-41

*Indicates JEDEC Registered Data

1N4728 thru 1N4764 (continued)
1M110ZS10 thru 1M200ZS10

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) *V_F = 1.5 V max, I_F = 200 mA for all types

JEDEC Type No. (Note 1)	Motorola Type No. (Note 2)	*Nominal Zener Voltage V_Z @ I_{ZT} Volts (Note 2 & 3)	*Test Current I_{ZT} mA	*Max Zener Impedance (Note 4)			*Leakage Current		*Surge Current @ T_A = 25°C i_r – mA (Note 5)
				Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA	I_R µA Max	V_R @ Volts	
1N4728	1M3.3ZS10	3.3	76	10	400	1.0	100	1.0	1380
1N4729	1M3.6ZS10	3.6	69	10	400	1.0	100	1.0	1260
1N4730	1M3.9ZS10	3.9	64	9.0	400	1.0	50	1.0	1190
1N4731	1M4.3ZS10	4.3	58	9.0	400	1.0	10	1.0	1070
1N4732	1M4.7ZS10	4.7	53	8.0	500	1.0	10	1.0	970
1N4733	1M5.1ZS10	5.1	49	7.0	550	1.0	10	1.0	890
1N4734	1M5.6ZS10	5.6	45	5.0	600	1.0	10	2.0	810
1N4735	1M6.2ZS10	6.2	41	2.0	700	1.0	10	3.0	730
1N4736	1M6.8ZS10	6.8	37	3.5	700	1.0	10	4.0	660
1N4737	1M7.5ZS10	7.5	34	4.0	700	0.5	10	5.0	605
1N4738	1M8.2ZS10	8.2	31	4.5	700	0.5	10	6.0	550
1N4739	1M9.1ZS10	9.1	28	5.0	700	0.5	10	7.0	500
1N4740	1M10ZS10	10	25	7.0	700	0.25	10	7.6	454
1N4741	1M11ZS10	11	23	8.0	700	0.25	5.0	8.4	414
1N4742	1M12ZS10	12	21	9.0	700	0.25	5.0	9.1	380
1N4743	1M13ZS10	13	19	10	700	0.25	5.0	9.9	344
1N4744	1M15ZS10	15	17	14	700	0.25	5.0	11.4	304
1N4745	1M16ZS10	16	15.5	16	700	0.25	5.0	12.2	285
1N4746	1M18ZS10	18	14	20	750	0.25	5.0	13.7	250
1N4747	1M20ZS10	20	12.5	22	750	0.25	5.0	15.2	225
1N4748	1M22ZS10	22	11.5	23	750	0.25	5.0	16.7	205
1N4749	1M24ZS10	24	10.5	25	750	0.25	5.0	18.2	190
1N4750	1M27ZS10	27	9.5	35	750	0.25	5.0	20.6	170
1N4751	1M30ZS10	30	8.5	40	1000	0.25	5.0	22.8	150
1N4752	1M33ZS10	33	7.5	45	1000	0.25	5.0	25.1	135
1N4753	1M36ZS10	36	7.0	50	1000	0.25	5.0	27.4	125
1N4754	1M39ZS10	39	6.5	60	1000	0.25	5.0	29.7	115
1N4755	1M43ZS10	43	6.0	70	1500	0.25	5.0	32.7	110
1N4756	1M47ZS10	47	5.5	80	1500	0.25	5.0	35.8	95
1N4757	1M51ZS10	51	5.0	95	1500	0.25	5.0	38.8	90
1N4758	1M56ZS10	56	4.5	110	2000	0.25	5.0	42.6	80
1N4759	1M62ZS10	62	4.0	125	2000	0.25	5.0	47.1	70
1N4760	1M68ZS10	68	3.7	150	2000	0.25	5.0	51.7	65
1N4761	1M75ZS10	75	3.3	175	2000	0.25	5.0	56.0	60
1N4762	1M82ZS10	82	3.0	200	3000	0.25	5.0	62.2	55
1N4763	1M91ZS10	91	2.8	250	3000	0.25	5.0	69.2	50
1N4764	1M100ZS10	100	2.5	350	3000	0.25	5.0	76.0	45
–	1M110ZS10	110	2.3	450	4000	0.25	5.0	83.6	–
–	1M120ZS10	120	2.0	550	4500	0.25	5.0	91.2	–
–	1M130ZS10	130	1.9	700	5000	0.25	5.0	98.8	–
–	1M150ZS10	150	1.7	1000	6000	0.25	5.0	114.0	–
–	1M160ZS10	160	1.6	1100	6500	0.25	5.0	121.6	–
–	1M180ZS10	180	1.4	1200	7000	0.25	5.0	136.8	–
–	1M200ZS10	200	1.2	1500	8000	0.25	5.0	152.0	–

*Indicates JEDEC Registered Data

NOTE 1 – TOLERANCE AND TYPE NUMBER DESIGNATION

The JEDEC type numbers listed have a standard tolerance on the nominal zener voltage of ±10%. A standard tolerance of ±5% on individual units is also available and is indicated by suffixing "A" to the standard type number.

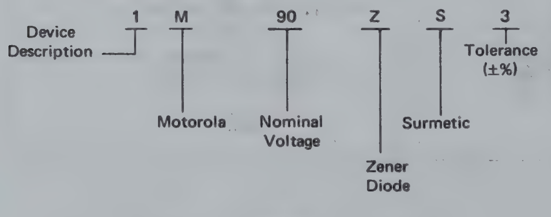
NOTE 2 – SPECIALS AVAILABLE INCLUDE:

(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES: To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±5%, ±3%, ±2%, ±1%), the Motorola type number should be used.

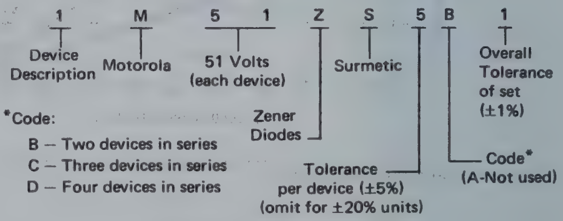
(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%).

Zener diodes can be obtained in sets consisting of two or more matched devices. The method for specifying such matched sets is similar to the one described in (A), except that two extra suffixes are added to the code number described.

These units are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set being ordered.



Example: **1M90ZS3**

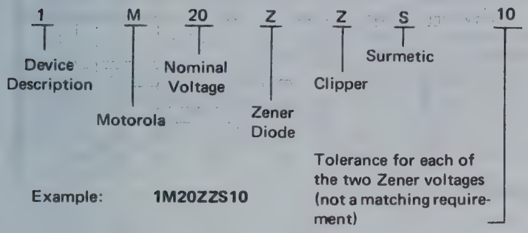


*Code:
B – Two devices in series
C – Three devices in series
D – Four devices in series

Example: **1M51ZS5B1**

(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:



Example: **1M20ZZS10**

NOTE 3 – ZENER VOLTAGE (V_Z) MEASUREMENT

Motorola guarantees the zener voltage when measured at 90 seconds while maintaining the lead temperature (T_L) at 30°C ± 1°C, 3/8″ from the diode body.

NOTE 4 – ZENER IMPEDANCE (Z_Z) DERIVATION

The zener impedance is derived from the 60 cycle ac voltage, which results when an ac current having an rms value equal to 10% of the dc zener current (I_{ZT} or I_{ZK}) is superimposed on I_{ZT} or I_{ZK}.

NOTE 5 – SURGE CURRENT (i_r) NON-REPETITIVE

The rating listed in the electrical characteristics table is maximum peak, non-repetitive, reverse surge current of 1/2 square wave or equivalent sine wave pulse of 1/120 second duration superimposed on the test current, I_{ZT}, per JEDEC registration, however, actual device capability is as described in Figures 4 and 5.

APPLICATION NOTE

Since the actual voltage available from a given zener diode is temperature dependent, it is necessary to determine junction temperature under any set of operating conditions in order to calculate its value. The following procedure is recommended:

Lead Temperature, T_L, should be determined from:

$$T_L = \theta_{LA} P_D + T_A$$

θ_{LA} is the lead-to-ambient thermal resistance (°C/W) and P_D is the power dissipation. The value for θ_{LA} will vary and depends on the device mounting method. θ_{LA} is generally 30-40°C/W for the various clips and tie points in common use and for printed circuit board wiring.

The temperature of the lead can also be measured using a thermocouple placed on the lead as close as possible to the tie point. The thermal mass connected to the tie point is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_L, the junction temperature may be determined by:

$$T_J = T_L + \Delta T_{JL}$$

ΔT_{JL} is the increase in junction temperature above the lead temperature and may be found from Figure 2 for a train of power pulses (L = 3/8 inch) or from Figure 3 for dc power.

$$\Delta T_{JL} = \theta_{JL} P_D$$

For worst-case design, using expected limits of I_Z, limits of P_D and the extremes of $T_J(\Delta T_J)$ may be estimated. Changes in voltage, V_Z, can then be found from:

$$\Delta V = \theta_{VZ} \Delta T_J$$

θ_{VZ}, the zener voltage temperature coefficient, is found from Figures 6 and 7.

Under high power-pulse operation, the zener voltage will vary with time and may also be affected significantly by the zener resistance. For best regulation, keep current excursions as low as possible.

Data of Figure 2 should not be used to compute surge capability. Surge limitations are given in Figure 4. They are lower than would be expected by considering only junction temperature, as current crowding effects cause temperatures to be extremely high in small spots resulting in device degradation should the limits of Figure 4 be exceeded.

FIGURE 2 — TYPICAL THERMAL RESPONSE, LEAD LENGTH L = 3/8 INCH

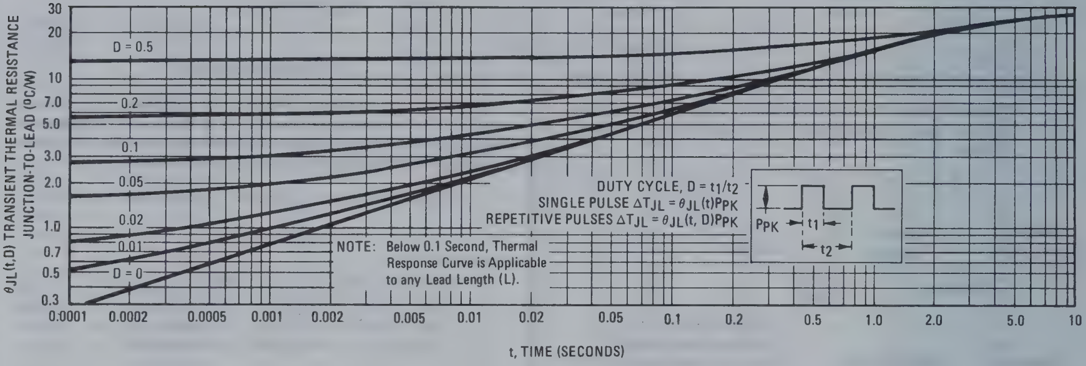


FIGURE 3 — TYPICAL THERMAL RESISTANCE

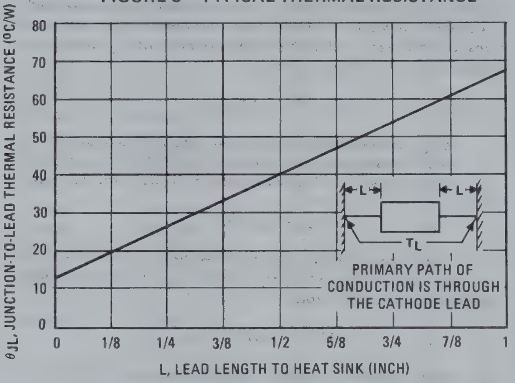


FIGURE 4 — MAXIMUM NON-REPETITIVE SURGE POWER

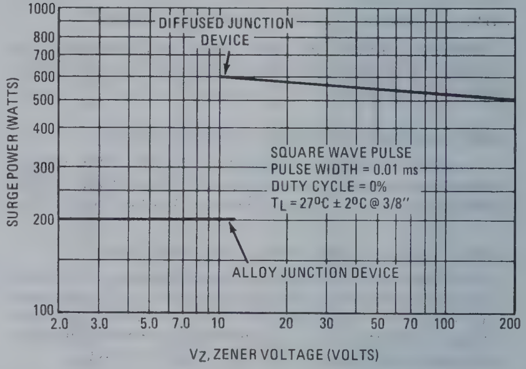
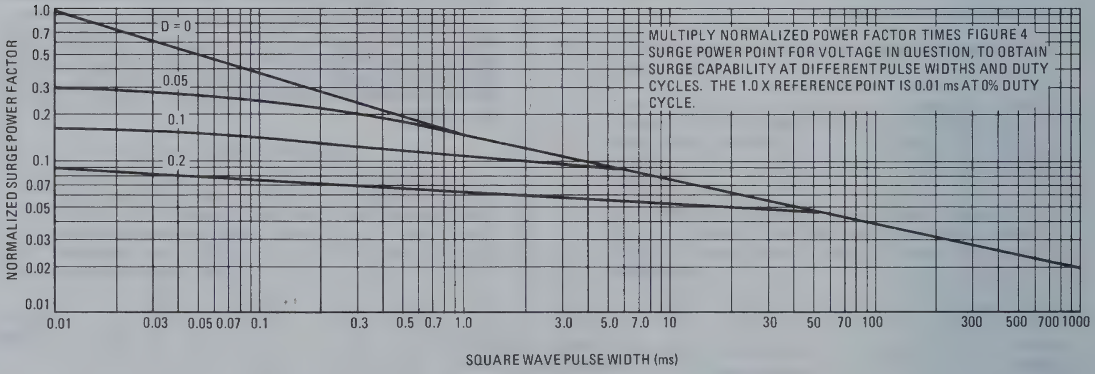


FIGURE 5 — SURGE POWER FACTOR



TEMPERATURE COEFFICIENTS AND VOLTAGE REGULATION

(90% OF THE UNITS ARE IN THE RANGES INDICATED)

FIGURE 6 — TEMPERATURE COEFFICIENT-RANGE FOR UNITS TO 12 VOLTS

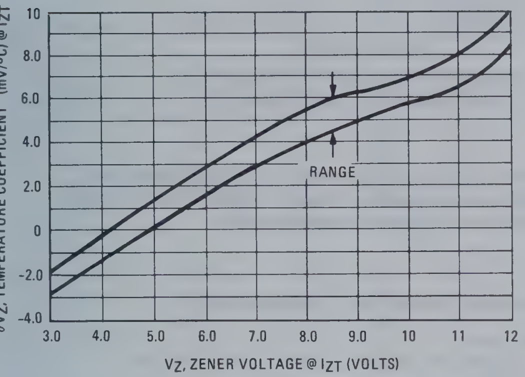


FIGURE 7 — TEMPERATURE COEFFICIENT-RANGE FOR UNITS 10 TO 200 VOLTS

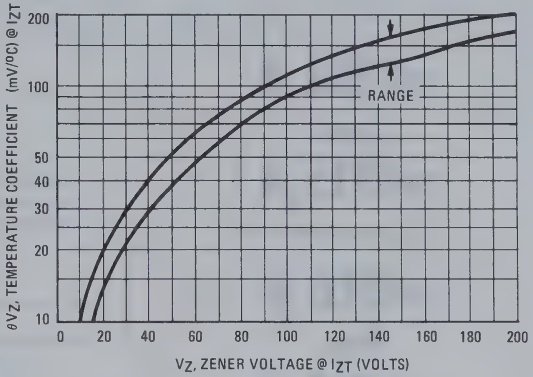


FIGURE 8 — VOLTAGE REGULATION

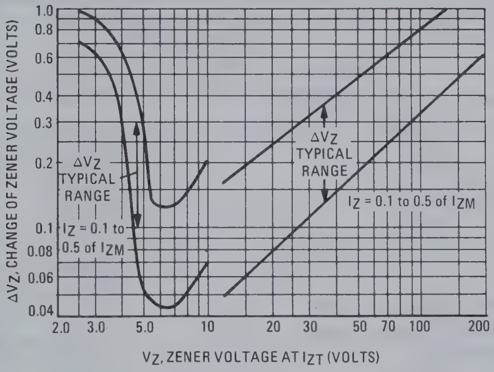
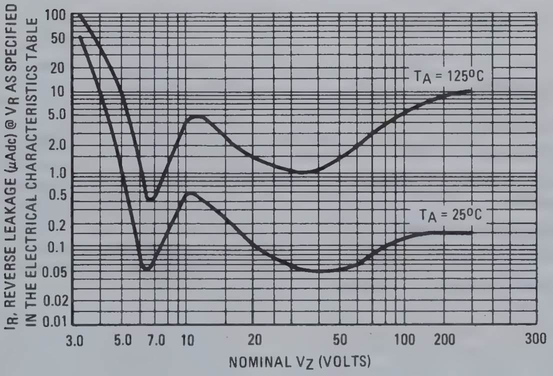


FIGURE 9 — MAXIMUM REVERSE LEAKAGE
(95% OF THE UNITS ARE BELOW THE VALUES SHOWN)



1N4765 thru 1N4774
1N4775 thru 1N4784

For Specifications, See 1N4565 Data.

1N4896,A
thru
1N4915,A

12.8 V ± 5.0%

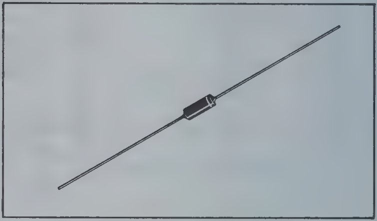
1N4916,A
thru
1N4932,A

19.2 V ± 5.0%

LOW NOISE TEMPERATURE-COMPENSATED ZENER REFERENCE DIODES

Highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

- Low Noise Density Specified for Critical Applications
- Low Power Drain
  Devices Specified @ 0.5 mA, 1.0 mA, 2.0 mA, 4.0 mA, and 7.5 mA
- Maximum Voltage Change Specified over Test Temperature Range
- Temperature Compensation Guaranteed over Two Standard Operating Temperature Ranges:
  +25 to +100°C
  -55 to +100°C



MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C

DC Power Dissipation: 400 Milliwatts at 50°C Ambient (Derate 3.2 mW/°C Above 50°C)

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

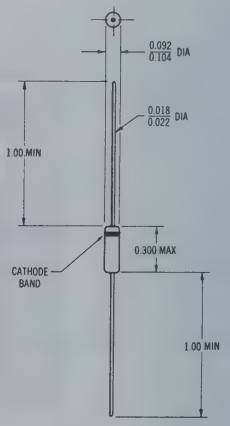
DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any



CASE 51
DO-7

1N4896, A thru 1N4915A, 1N4916, thru 1N4932, A (continued)

$V_Z = 12.8$ V

TEMPERATURE RANGE:

STANDARD DEVICES
+25, +75, +100°C

"A" SUFFIX
-55, 0 + 25, +75, +100°C

Type Number	ΔV_Z Volts (Note 1)	Temp. Coeff. for Ref. %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
$I_{ZT} = 0.5$ mA *$N_D = 0.8 \frac{\mu V}{\sqrt{Hz}}$			
1N4896	0.096	0.01	400
1N4896A	0.198	0.01	
1N4897	0.048	0.005	
1N4897A	0.099	0.005	
1N4898	0.019	0.002	
1N4898A	0.040	0.002	
1N4899	0.010	0.001	
1N4899A	0.020	0.001	
$I_{ZT} = 1.0$ mA *$N_D = 0.4 \frac{\mu V}{\sqrt{Hz}}$			
1N4900	0.096	0.01	200
1N4900A	0.198	0.01	
1N4901	0.048	0.005	
1N4901A	0.099	0.005	
1N4902	0.019	0.002	
1N4902A	0.040	0.002	
1N4903	0.010	0.001	
1N4903A	0.020	0.001	
$I_{ZT} = 2.0$ mA *$N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$			
1N4904	0.096	0.01	100
1N4904A	0.198	0.01	
1N4905	0.048	0.005	
1N4905A	0.099	0.005	
1N4906	0.019	0.002	
1N4906A	0.040	0.002	
1N4907	0.010	0.001	
1N4907A	0.020	0.001	
$I_{ZT} = 4.0$ mA *$N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$			
1N4908	0.096	0.01	50
1N4908A	0.198	0.01	
1N4909	0.048	0.005	
1N4909A	0.099	0.005	
1N4910	0.019	0.002	
1N4910A	0.040	0.002	
1N4911	0.010	0.001	
1N4911A	0.020	0.001	
$I_{ZT} = 7.5$ mA *$N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$			
1N4912	0.096	0.01	25
1N4912A	0.198	0.01	
1N4913	0.048	0.005	
1N4913A	0.099	0.005	
1N4914	0.019	0.002	
1N4914A	0.040	0.002	
1N4915	0.010	0.001	
1N4915A	0.020	0.001	

$V_Z = 19.2$ V

TEMPERATURE RANGE:

STANDARD DEVICES
+25, +75, +100°C

"A" SUFFIX
-55, 0, +25, +75, +100°C

Type Number	ΔV_Z Volts (Note 1)	Temp. Coeff. for Ref. %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
$I_{ZT} = 0.5$ mA *$N_D = 1.0 \frac{\mu V}{\sqrt{Hz}}$			
1N4916	0.144	0.01	600
1N4916A	0.298	0.01	
1N4917	0.072	0.005	
1N4917A	0.149	0.005	
1N4918	0.029	0.002	
1N4918A	0.060	0.002	
$I_{ZT} = 1.0$ mA *$N_D = 0.5 \frac{\mu V}{\sqrt{Hz}}$			
1N4919	0.144	0.01	300
1N4919A	0.298	0.01	
1N4920	0.072	0.005	
1N4920A	0.149	0.005	
1N4921	0.029	0.002	
1N4921A	0.060	0.002	
$I_{ZT} = 2.0$ mA *$N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$			
1N4922	0.144	0.01	150
1N4922A	0.298	0.01	
1N4923	0.072	0.005	
1N4923A	0.149	0.005	
1N4924	0.029	0.002	
1N4924A	0.060	0.002	
$I_{ZT} = 4.0$ mA *$N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$			
1N4925	0.144	0.01	75
1N4925A	0.298	0.01	
1N4926	0.072	0.005	
1N4926A	0.149	0.005	
1N4927	0.029	0.002	
1N4927A	0.060	0.002	
1N4928	0.014	0.001	
1N4928A	0.030	0.001	
$I_{ZT} = 7.5$ mA *$N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$			
1N4929	0.144	0.01	36
1N4929A	0.298	0.01	
1N4930	0.072	0.005	
1N4930A	0.149	0.005	
1N4931	0.029	0.002	
1N4931A	0.060	0.002	
1N4932	0.014	0.001	
1N4932A	0.030	0.001	

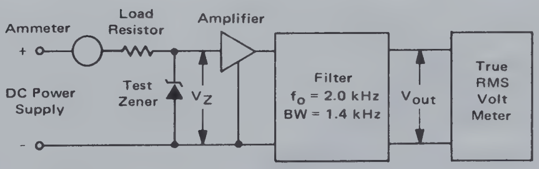
NOTE 1:
Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the max ΔV_Z given. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability — by means of temperature coefficient — accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 2: Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

*NOISE DENSITY MEASUREMENT METHOD



$$\text{Noise Density (Volts per Square Root Bandwidth)} = \frac{V_{out}}{\text{Overall Gain} \quad \text{BW}}$$

Where BW = Filter Bandwidth (Hz)
V_{out} Output Noise (Volts RMS)

The input voltage and load resistance are high so that the zener diode is driven from a constant current source. The amplifier is low noise so that the amplifier noise is negligible compared to that of the test TC zener. The filter bandpass is known so that the noise density can be calculated from the formula shown.

1N4933 thru 1N4937
MR2271

Designers Data Sheet

SUBMINIATURE SIZE, AXIAL LEAD MOUNTED FAST RECOVERY POWER RECTIFIERS

. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

Designer's Data for "Worst Case" Conditions

The Designers Data Sheet permits the design of most circuits entirely from the information presented. Limit curves — representing device characteristics boundaries — are given to facilitate "worst case" design.

***MAXIMUM RATINGS**

Rating	Symbol	1N4933	1N4934	1N4935	MR2271	1N4936	1N4937	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	300	400	600	Volts
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	250	350	450	650	Volts
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	210	280	420	Volts
Average Rectified Forward Current (Single phase, resistive load, $T_A = 75^\circ C$)	I_O	1.0						Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30						Amps
Operating Junction Temperature Range	T_J	-65 to +150						°C
Storage Temperature Range	T_{stg}	-65 to +175						°C

***THERMAL CHARACTERISTICS**

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient (Typical Printed Circuit Board Mounting)	$R_{\theta JC}$	65	°C/W

***ELECTRICAL CHARACTERISTICS**

Characteristic	Symbol	Min	Typ	Max	Unit
*Instantaneous Forward Voltage ($I_F = 3.14$ Amp, $T_J = 150^\circ C$)	V_F	–	1.0	1.2	Volts
Forward Voltage ($I_F = 1.0$ Amp, $T_A = 25^\circ C$)	V_F	–	1.0	1.1	Volts
*Reverse Current (rated dc voltage) $T_A = 25^\circ C$	I_R	–	1.0	5.0	μA
$T_A = 100^\circ C$		–	50	100	

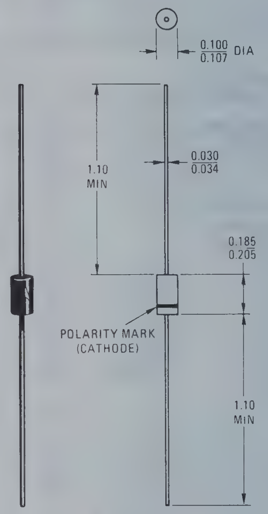
***REVERSE RECOVERY CHARACTERISTICS**

Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Recovery Time ($I_F = 1.0$ Amp to $V_R = 30$ Vdc) (Figure 21)	t_{rr}	–	100	200	ns
($I_{FM} = 15$ Amp, di/dt = 10 A/μs) (Figure 22)		–	150	300	
Reverse Recovery Current ($I_F = 1.0$ Amp to $V_R = 30$ Vdc) (Figure 21)	$I_{RM(REC)}$	–	1.0	2.0	Amp

*Indicates JEDEC Registered Data for 1N4933 Series

FAST RECOVERY POWER RECTIFIERS

50-600 VOLTS 1 AMPERE



All JEDEC dimensions and notes apply

CASE 59
DO-41

MECHANICAL CHARACTERISTICS

CASE: Void Free, Transfer Molded

FINISH: External leads are gold plated, leads are readily solderable

POLARITY: Cathode indicated by Polarity band.

WEIGHT: 0.4 Gram (Approximately)

FIGURE 1 – FORWARD VOLTAGE

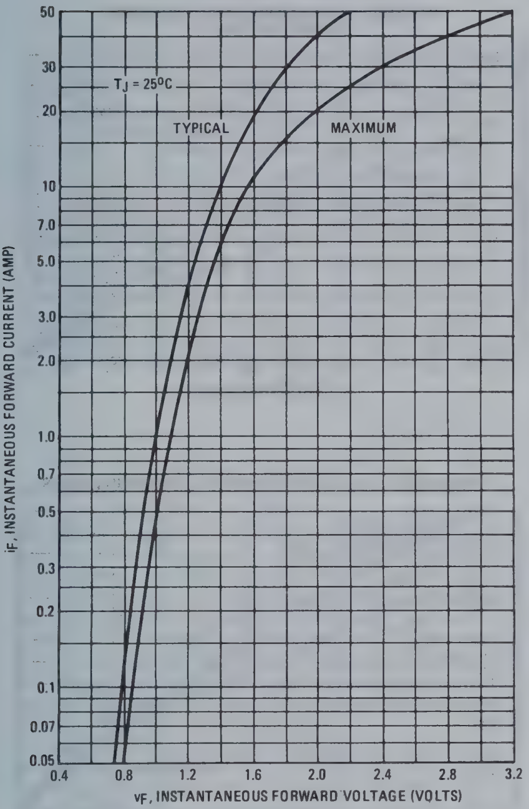


FIGURE 2 – MAXIMUM SURGE CAPABILITY

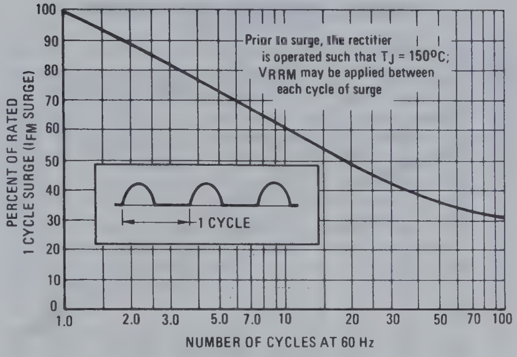
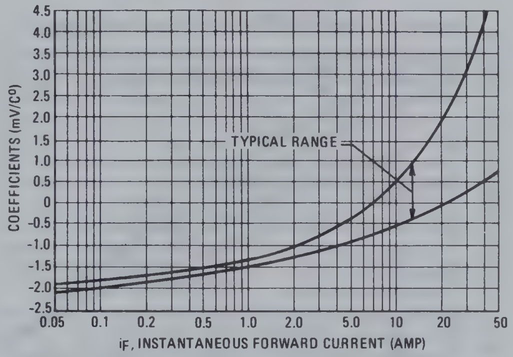
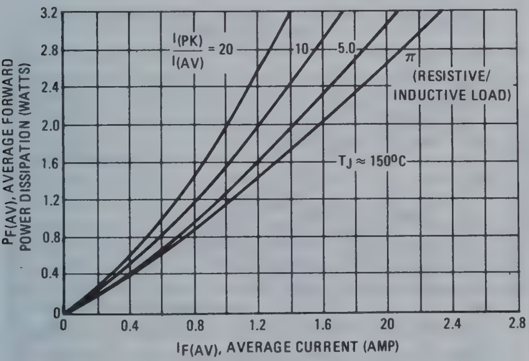


FIGURE 3 – FORWARD VOLTAGE TEMPERATURE COEFFICIENT



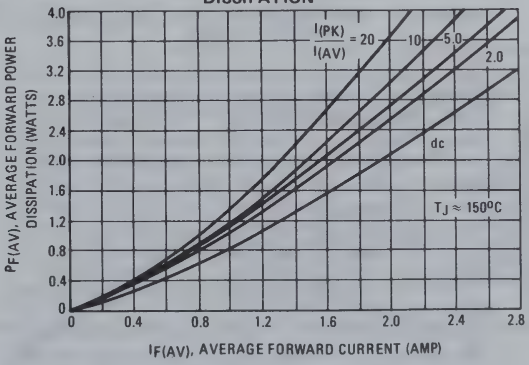
SINE WAVE INPUT

FIGURE 4 – FORWARD POWER DISSIPATION



SQUARE WAVE INPUT

FIGURE 5 – FORWARD POWER DISSIPATION



MAXIMUM CURRENT RATINGS

SINE WAVE INPUT

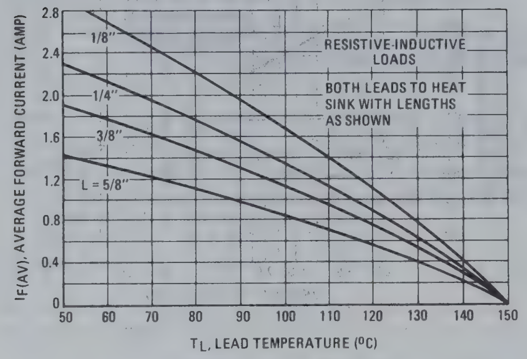


FIGURE 6 — EFFECT OF LEAD LENGTHS, RESISTIVE LOAD

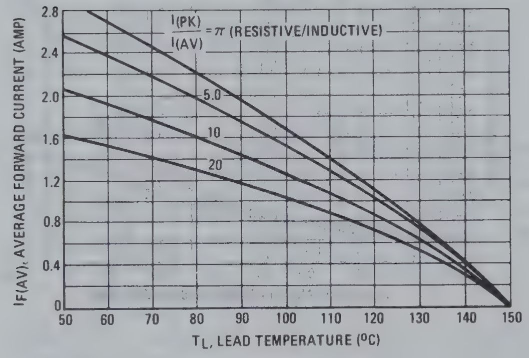


FIGURE 8 — 1/8″ LEAD LENGTH, VARIOUS LOADS

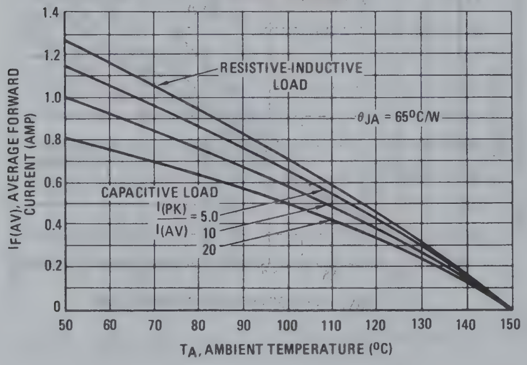


FIGURE 10 — PRINTED CIRCUIT BOARD MOUNTING, VARIOUS LOADS

SQUARE WAVE INPUT

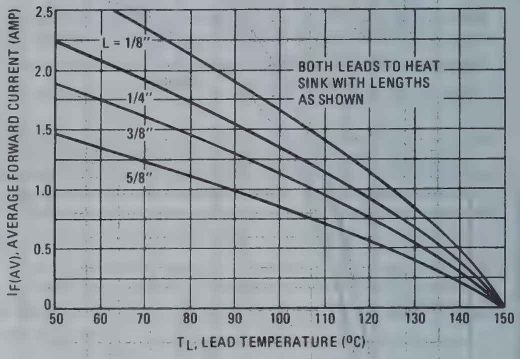


FIGURE 7 — EFFECT OF LEAD LENGTHS, RESISTIVE LOAD

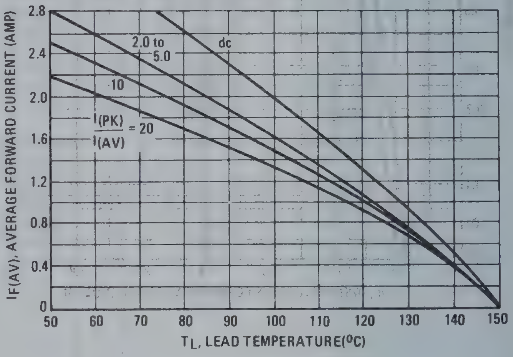


FIGURE 9 — 1/8″ LEAD LENGTHS, VARIOUS LOADS

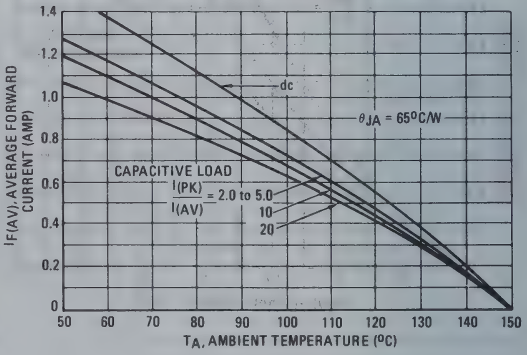


FIGURE 11 — PRINTED CIRCUIT BOARD MOUNTING, VARIOUS LOADS

FIGURE 12 – THERMAL RESPONSE

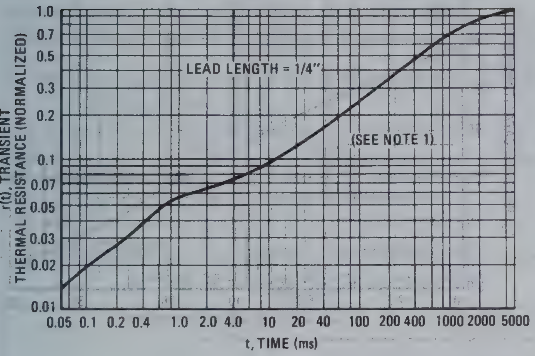
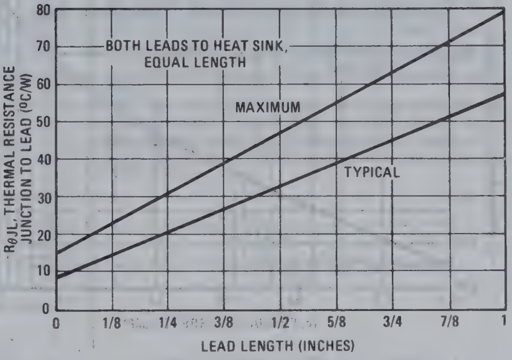
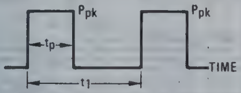


FIGURE 13 – THERMAL RESISTANCE



NOTE 1



DUTY CYCLE, $D = t_p/t_1$
PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the case should be measured using a thermocouple placed on the case at the temperature reference point (see Note 3). The thermal mass connected to the case is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_C, the junction temperature may be determined by:

$$T_J = T_C + \Delta T_{JC}$$

where ΔT_{JC} is the increase in junction temperature above the case temperature. It may be determined by:

$$\Delta T_{JC} = P_{pk} \cdot R_{\theta JC} [D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) - r(t_1)]$$

where

$r(t)$ = normalized value of transient thermal resistance at time, t, from Figure 3, i.e.:

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

NOTE 2

Data shown for thermal resistance junction-to-ambient (θ_{JA}) for the mountings shown is to be used as typical guideline values for preliminary engineering or in case the tie point temperature cannot be measured.

TYPICAL VALUES FOR θ_{JA} IN STILL AIR

MOUNTING METHOD	LEAD LENGTH, L (IN)				$R_{\theta JA}$
	1/8	1/4	1/2	3/4	
1	65	72	82	92	°C/W
2	74	81	91	101	°C/W
3	40				°C/W

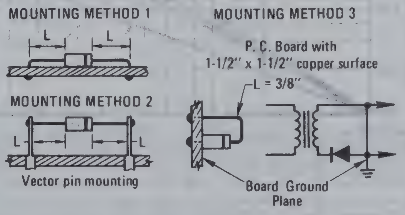
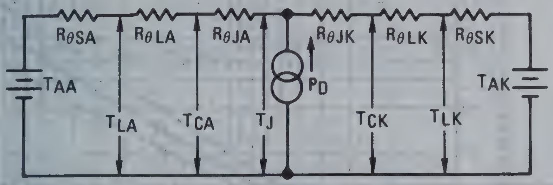


FIGURE 14 – THERMAL CIRCUIT MODEL
(For Heat Conduction Through The Leads)



Use of the above model permits junction to lead thermal resistance for any mounting configuration to be found. For a given total lead length, lowest values occur when one side of the rectifier is brought as close as possible to the heat sink. Terms in the model signify:

T_A = Ambient Temperature
T_L = Lead Temperature
T_C = Case Temperature
T_J = Junction Temperature
$R_{\theta S}$ = Thermal Resistance, Heat Sink to Ambient
$R_{\theta L}$ = Thermal Resistance, Lead to Heat Sink
$R_{\theta J}$ = Thermal Resistance, Junction to Case
P_D = Power Dissipation

(Subscripts A and K refer to anode and cathode sides respectively.)

Values for thermal resistance components are:

$R_{\theta L}$ = 112°C/W/IN. Typically and 128°C/W/IN Maximum
$R_{\theta J}$ = 18°C/W Typically and 30°C/W Maximum

The maximum lead temperature may be calculated as follows:

$$T_L = 150^{\circ} - \Delta T_{JL}$$

ΔT_{JL} can be calculated as shown in NOTE 1 or it may be approximated as follows:

$\Delta T_{JL} \approx R_{\theta JL} \bullet P_F$; P_F may be formulated for sine-wave operation from Figure 3 or from Figure 4 for square-wave operation.

TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 15 – FORWARD RECOVERY TIME

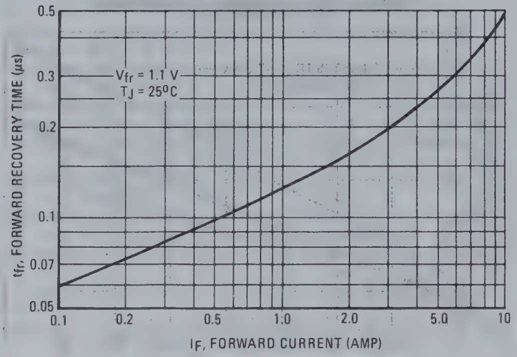
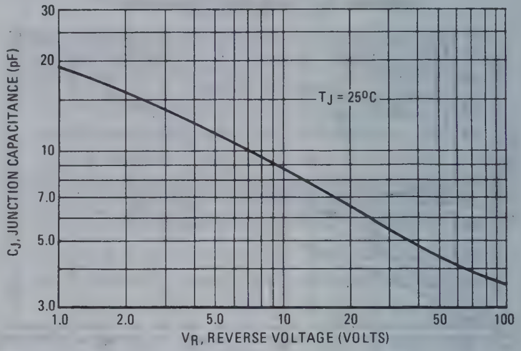


FIGURE 16 – JUNCTION CAPACITANCE



TYPICAL RECOVERED STORED CHARGED DATA

FIGURE 17 – T_J = 25°C

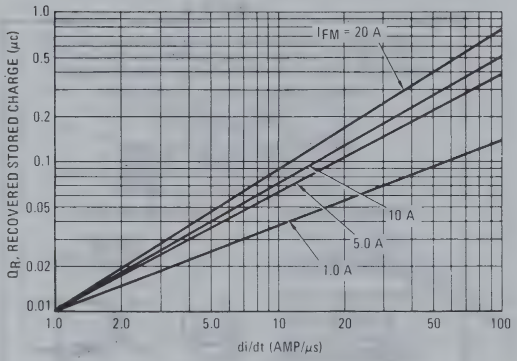


FIGURE 18 – T_J = 75°C

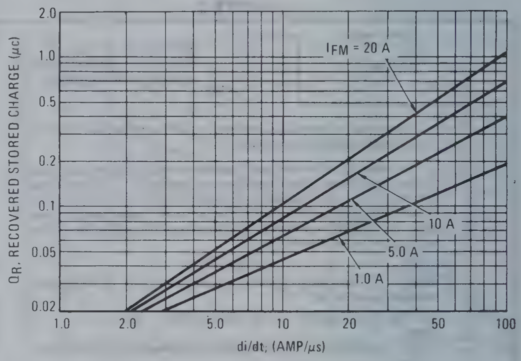


FIGURE 19 – T_J = 100°C

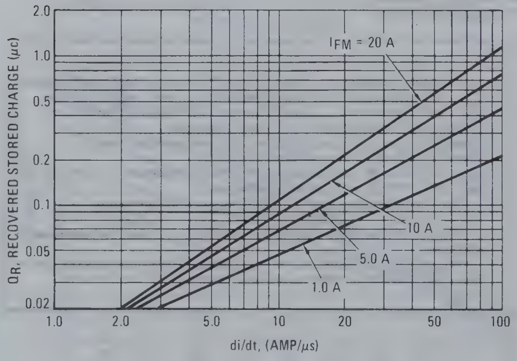
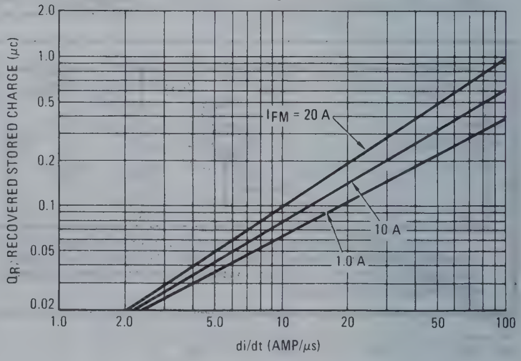
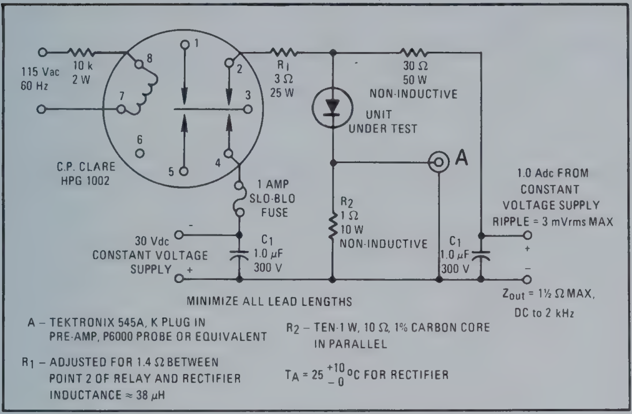


FIGURE 20 – T_J = 150°C



RECOVERY TIME

FIGURE 21 – REVERSE RECOVERY CIRCUIT


115 Vac
60 Hz
10 k
2 W
8
1
2
3
7
6
5
4
C.P. CLARE
HPG 1002
R1
3 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1 AMP
SLO-BLO
FUSE
R2
1 Ω
10 W
NON-INDUCTIVE
1.0 Adc FROM
CONSTANT
VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
30 Vdc
CONSTANT VOLTAGE
SUPPLY
C1
1.0 μF
300 V
C1
1.0 μF
300 V
Zout = 1½ Ω MAX,
DC to 2 kHz

MINIMIZE ALL LEAD LENGTHS

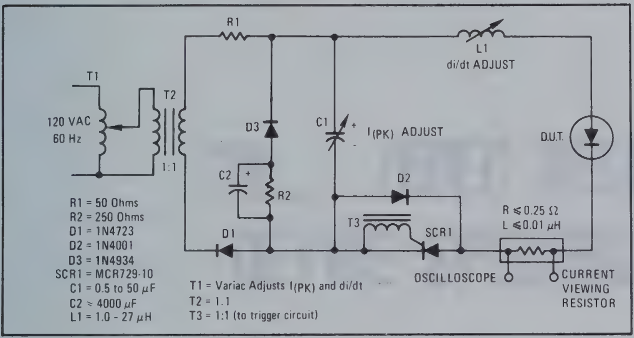
A – TEKTRONIX 545A, K PLUG IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_2 – TEN-1 W, 10 Ω, 1% CARBON CORE IN PARALLEL

R_1 – ADJUSTED FOR 1.4 Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER INDUCTANCE ≈ 38 μH

$T_A = 25\,^{+10}_{-0}\,^{\circ}C$ FOR RECTIFIER

FIGURE 22 – JEDEC REVERSE RECOVERY CIRCUIT


R1
L1
di/dt ADJUST
T1
T2
120 VAC
60 Hz
1:1
D3
C1
I(PK) ADJUST
D.U.T.
C2
R2
D2
T3
SCR1
D1
R ≤ 0.25 Ω
L ≤ 0.01 μH
OSCILLOSCOPE
CURRENT
VIEWING
RESISTOR

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4934
SCR1 = MCR729-10
C1 = 0.5 to 50 μF
C2 ≈ 4000 μF
L1 = 1.0 - 27 μH

T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)

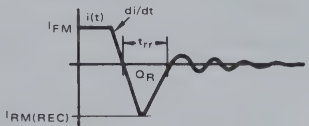
NOTE 3

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using I_F = 1.0 A, V_R = 30 V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.


IFM
i(t)
di/dt
trr
QR
IRM(REC)

From stored charge curves versus di/dt, recovery time (t_{rr}) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

FIGURE 23 – TYPICAL REVERSE LEAKAGE

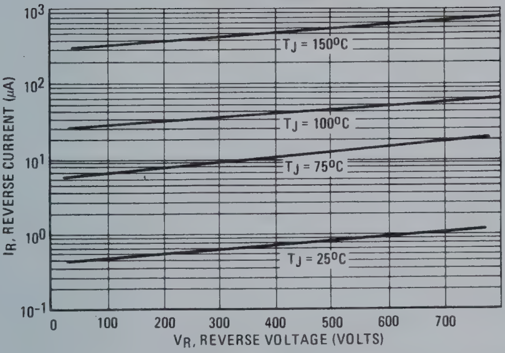
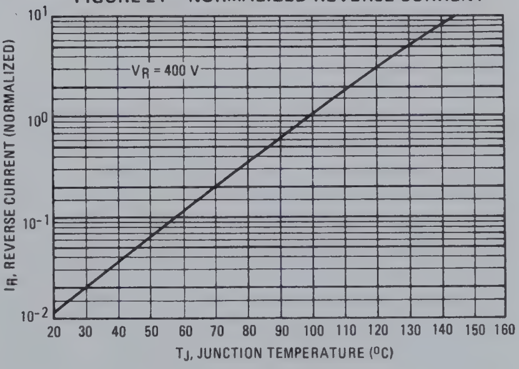


FIGURE 24 – NORMALIZED REVERSE CURRENT



1N4997 thru 1N5003

For Specifications, See 1N4719 Data.

2N... JEDEC REGISTERED DEVICE SPECIFICATIONS

2N173 (GERMANIUM)

For Specifications, See 2N277 Data.

2N174 (GERMANIUM)
2N1100
2N1358,A

CASE 5
(TO-36)

PNP germanium power transistors. Power dissipation and junction temperature ratings exceed those of EIA registration.

MAXIMUM RATINGS

Rating	Symbol	2N174	2N1100	2N1358	Unit
Collector-Base Voltage	V_{CB}	80	100	80	Vdc
Emitter-Base Voltage	V_{EB}	60	80	60	Vdc
Emitter Current (Continuous)	I_E	15	15	15	Amp
Base Current (Continuous)	I_B	4.0	4.0	4.0	Amp
Junction and Storage Temperature	T_J, T_{stg}	-65 to +110			°C
Thermal Resistance, Junction to Case	θ_{JC}	0.5			°C/W

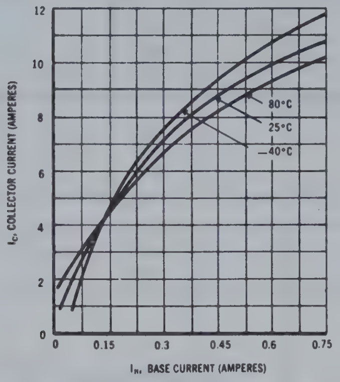
2N174, 2N1100, 2N1358 (continued)

ELECTRICAL CHARACTERISTICS

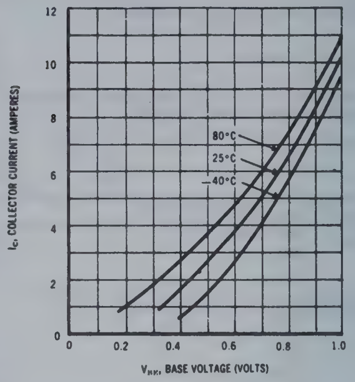
Characteristic		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current (V_{CB} = 2 volts)	2N174	I_{CBO}	-	100	-	μA
	2N1100		-	100	-	
	2N1358		-	100	200	
Collector-Base Cutoff Current (V_{EB} = 1.5 volts, V_{CB} = 80 volts)	2N174	I_{CBO}	-	2.0	8.0	mA
100	2N1100		-	2.0	8.0	
80	2N1358		-	2.0	8.0	
Emitter-Base Cutoff Current (V_{EB} = 60 volts)	2N174	I_{EBO}	-	1.0	8.0	mA
80	2N1100		-	1.0	8.0	
60	2N1358		-	1.0	8.0	
Collector-Base Cutoff Current (V_{CB} = 80 volts, 71°C)	2N174	I_{CBO}	-	-	15	mA
100	2N1100		-	-	15	
60	2N1358		-	4.0	6.0	
Emitter-Base Cutoff Current (V_{EB} = 30 volts, 71°C)	2N1358	I_{EBO}	-	4.0	6.0	mA
Collector-Emitter Voltage (I_C = 300 mA, V_{EB} = 0)	2N174	BV_{CES}*	70	-	-	Vdc
	2N1100		80	-	-	
	2N1358		70	-	-	
Collector-Emitter Voltage (I_C = 1.0 amp, I_B = 0)	2N174	BV_{CEO}*	55	-	-	Vdc
1.0 amp, I_B = 0	2N1100		65	-	-	
300 mA, I_B = 0	2N1358		40	-	-	
Floating Potential (I_E = 0, V_{CB} = 80 volts)	2N174	V_{EBF}	-	-	1.0	volt
100	2N1100		-	-	1.0	
80	2N1358		-	0.15	1.0	
Current Gain (I_C = 1.2 amp, V_{CB} = 2 volts)	2N1358	h_{FE}	40	55	80	-
(I_C = 5 amp, V_{CB} = 2 volts)	2N174		25	-	50	
	2N1100		25	-	50	
	2N1358		25	35	-	
(I_C = 12 amp, V_{CB} = 2 volts)	2N174		-	20	-	
	2N1100		-	20	-	
Base-Emitter Voltage (I_C = 1.2 amp, V_{CB} = 2 volts)	2N1358	V_{BE}	-	0.35	0.5	Vdc
(I_C = 5 amp, V_{CB} = 2 volts)	2N174		-	0.65	0.9	
	2N1100		-	0.65	0.9	
	2N1358		-	0.65	0.9	
Saturation Voltage (I_C = 12 amp, I_B = 2 amp)	2N174	$V_{CE(sat)}$	-	0.3	0.9	Vdc
	2N1100		-	0.3	0.7	
	2N1358		-	0.3	0.7	
Common-Emitter Cutoff Frequency (I_C = 5 amp, V_{CE} = 6 volts)	2N174	$f_{\alpha e}$	-	10	-	kHz
	2N1100					
Common-Base Cutoff Frequency (I_E = 1 amp, V_{CB} = 12 volts)	2N1358	$f_{\alpha b}$	100	-	-	kHz
Rise Time ("on" I_C = 12 Adc, I_B = 2 Adc, V_{CE} = 12 volts)		t_r	-	15	-	μs
Fall Time ("off" I_C = 0, V_{EB} = -6 volts, R_{EB} = 10 ohms)		t_f	-	15	-	μs

* In order to avoid excessive heating of the collector junction, perform test by the sweep method.

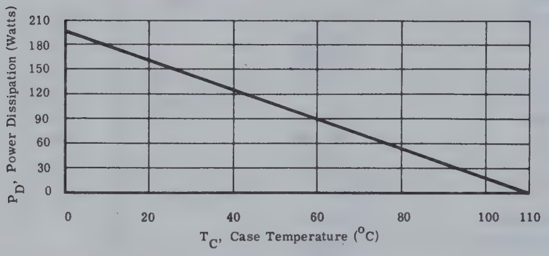
CURRENT TRANSFER CHARACTERISTICS



TRANSCONDUCTANCE CHARACTERISTICS



POWER-TEMPERATURE DERATING CURVE

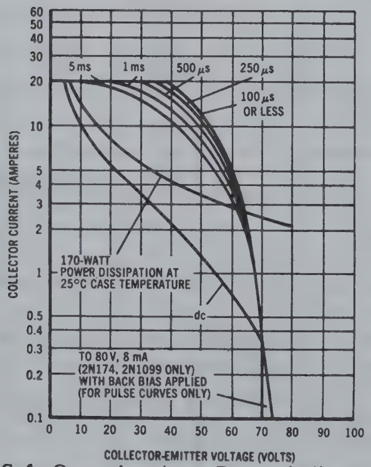


The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

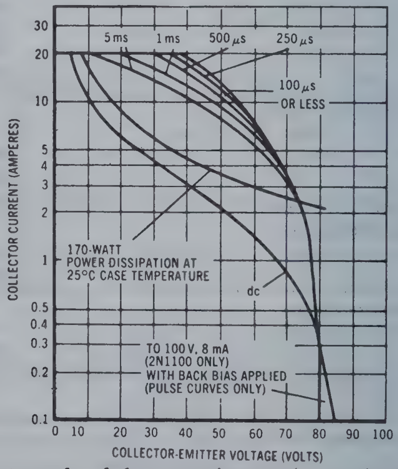
This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110^\circ - T_C}{0.5}$$

2N174 AND 1358



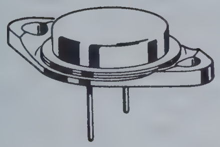
2N1100



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short.

(Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N176 (GERMANIUM)
2N669

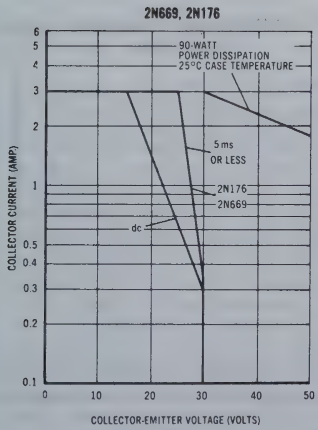


CASE 11
(TO-3)

PNP germanium power transistors for economical power switching circuits and commercial grade power amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector Current (Continuous)	I_C	3.0	Amp
Storage and Junction Temperature	T_J, T_{stg}	−65 to +100	°C
Total Device Dissipation (At 25°C Case Temperature)	P_D	90	Watts
Thermal Resistance (Junction to Case)	θ_{JC}	0.8	°C/W



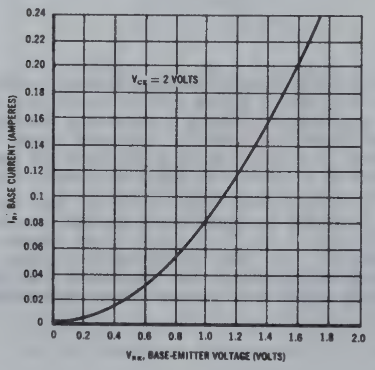
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

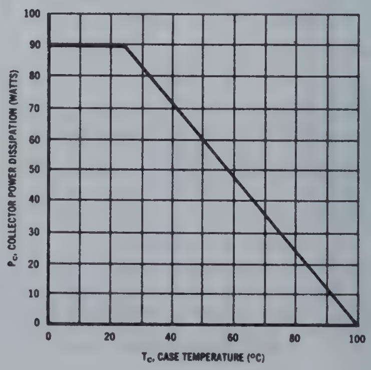
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current		I_{CBO}				
$V_{CB} = 30$ V, $I_E = 0$			—	—	3.0	mA
$V_{CB} = 2.0$ V, $I_E = 0$			—	50	—	µA
$V_{CB} = 30$ V, $I_E = 0$, $T_C = 90°C$			—	—	20	mA
Emitter-Base Cutoff Current $V_{EB} = 10$ V, $I_C = 0$		I_{EBO}	—	—	2.0	mA
Collector-Emitter Breakdown Voltage $I_C = 330$ mA, $R_{BE} = 10$ Ohms	2N176	BV_{CER}	30	—	—	Vdc
	2N669	BV_{CES}	30	—	—	
Collector-Emitter Saturation Voltage $I_C = 3$ A, $I_B = 300$ mA		$V_{CE(SAT)}$	—	—	0.4	Vdc
DC Forward Current Transfer Ratio $V_{CE} = 2.0$ V, $I_C = 0.5$ A	2N176	h_{FE}	25	—	—	—
	2N669		75	—	250	
Power Gain $P_{out} = 2$ Watts, $V_{CE} = 12$ V, $I_C = 0.5$ Amp, f = 1 kHz, $R_S = 10$ Ohms, $R_L = 26.6$ Ohms	2N176	G_{PE}	34	—	37	dB
	2N669		38	—	—	
Total Harmonic Distortion (under same conditions of power gain)			—	—	5.0	%
Small-Signal Current Gain Cutoff Frequency $V_{CE} = 12$ V, $I_C = 0.5$ Amp, f = 1 kHz ref	2N176	$f_{\alpha e}$	4.0	7.0	—	kHz
	2N669		3.0	5.0	—	
Small-Signal Forward-Current Transfer Ratio $V_{CE} = 2.0$ V, $I_C = 0.5$ Amp, f = 1 kHz	2N176	h_{fe}	—	45	—	—
	2N669		—	90	—	
Small-Signal Input Impedance $V_{CE} = 2.0$ V, $I_C = 0.5$ Amp, f = 1 kHz	2N176	h_{ie}	7.0	—	25	Ohms
	2N669		10	—	50	

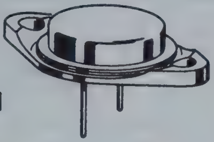
INPUT CURRENT versus EMITTER DRIVE VOLTAGE
(Both Types)



POWER-TEMPERATURE DERATING CURVE
(Both Types)



2N178 (GERMANIUM)
2N554
2N555

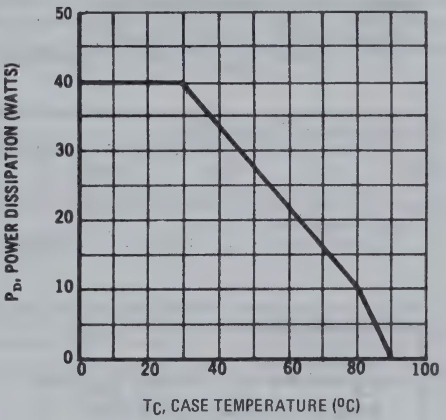


PNP germanium power transistor for non-critical power amplifier and power switching applications requiring economical components.

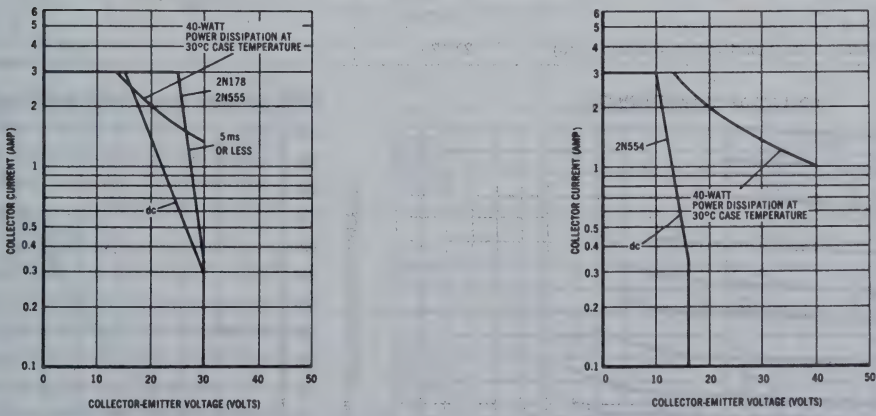
MAXIMUM RATINGS

Rating	Symbol	2N178	2N554	2N555	Unit
Collector-Emitter Voltage	V_{CER}	30	16	30	Vdc
Collector-Base Voltage	V_{CB}	30	15	30	Vdc
Emitter-Base Voltage	V_{EB}	20	15	15	Vdc
Collector Current	I_C	3.0			Adc
Total Device Dissipation @ T_C = 80°C	P_D	10			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-40 to +90			°C

POWER-TEMPERATURE DERATING CURVE



SAFE OPERATING AREAS



2N178, 2N555

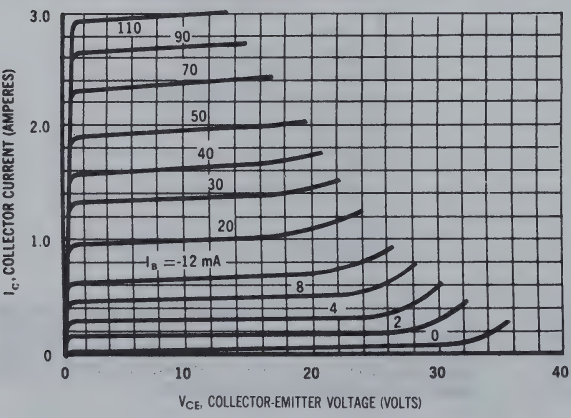
2N554

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

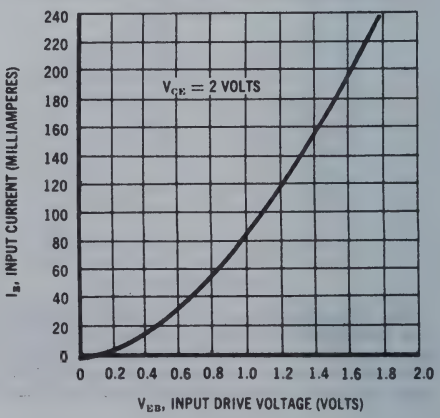
ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 330 mAdc, R_{BE} = 10Ω)	2N178	BV_{CER}	30	-	-	Vdc
	2N554		16	-	-	
	2N555		30	-	-	
Collector-Base Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	2N178	I_{CBO}	-	0.05	-	mA
(V_{VB} = 30 Vdc, I_E = 0)	2N178		-	-	3.0	
(V_{CB} = 15 Vdc, I_E = 0)	2N554		-	-	10.0	
(V_{CB} = 30 Vdc, I_E = 0)	2N555		-	-	20.0	
(V_{CB} = 30 Vdc, I_E = 0, T_C = 90° C)	2N178		-	-	20.0	
Emitter-Base Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	2N178	I_{EBO}	-	-	2.0	mA
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)	2N178	h_{FE}	15	-	45	-
	2N554		-	50	-	
	2N555		-	50		
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 300 mAdc)		$V_{CE(sat)}$	-	0.6	-	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Common-Emitter Cutoff Frequency (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 1.0 kHz ref)	2N178	$f_{\alpha e}$	5.0	-	-	kHz
	2N554		-	6.0	-	
	2N555		-	6.0	-	
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc, f = 1.0 kHz ref)	2N178	h_{fe}	-	30	-	-
	2N554		-	55	-	
	2N555		-	55	-	
Input Impedance (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc, f = 1.0 kHz)	2N178	h_{ie}	8.0	25	-	Ohms
	2N554		-	25	-	
	2N555		-	25	-	
FUNCTIONAL TESTS						
Power Gain (V_{CE} = 12 Vdc, I_C = 0.5 Adc, P_{out} = 2.0 Watts, f = 1.0 kHz, R_S = 10 Ohms, R_L = 26.6 Ohms)	2N178	G_{PE}	28	-	33	dB
	2N554		20	35	-	
	2N555		25	35	-	
Total Harmonic Distortion (Under same conditions as power gain)	2N178		-	-	5.0	%

COLLECTOR CHARACTERISTICS

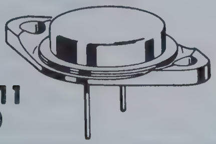


INPUT CURRENT versus INPUT DRIVE VOLTAGE



2N242 (GERMANIUM)

2N307, A



CASE 11
(TO-3)

PNP germanium power transistors for general purpose power amplifier and switching applications.

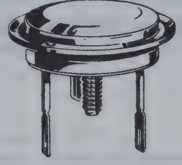
MAXIMUM RATINGS

Rating	Symbol	2N242	2N307, 307A	Unit
Collector-Base Voltage	V_{CB}	45	35	Volts
Collector-Emitter Voltage (R_{BE} = 30 Ω)	V_{CER}	45	—	Volts
Collector-Emitter Voltage	V_{CEO}	—	35	Volts
Emitter-Base Voltage	V_{EB}	—	10	Volts
Collector Current	I_C	5.0	5.0	Amp
Junction Temperature Range	T_J	-65 to + 110	-65 to +110	°C
Collector Dissipation (at T_C = 25°C)	P_D	106	106	Watts

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 2 Vdc)	2N307		—	0.5	
(V_{CB} = 25 Vdc)	2N307		—	5.0	
	2N307A		—	2.0	
(V_{CB} = 1 Vdc, I_E = 0, T_C = 85°C)	2N242		—	5.0	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 10 Vdc)			—	2.0	
Collector-Emitter Cutoff Current		I_{CER}			mAdc
(V_{CE} = 45 Vdc, R_{BE} = 30 Ω)	2N242		—	5.0	
(V_{CE} = 25 Vdc, R_{BE} = 30 Ω)	2N242		—	1.0	
(V_{CE} = 35 Vdc, R_{BE} = 30 Ω)	2N307		—	15	
	2N307A		—	7.0	
Base-Emitter Voltage		V_{BE}			Vdc
(V_{CE} = 1.5 Vdc, I_C = 1.0 Adc)	2N242		0.3	0.8	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 2.0 Adc, I_B = 200 mAdc)	2N242		—	0.8	
(I_C = 0.2 Adc, I_B = 20 mAdc)	2N307		—	1.0	
(I_C = 1.0 Adc, I_B = 100 mAdc)	2N307A		—	0.8	
DC Current Gain		h_{FE}			—
(V_{CE} = 12 Vdc, I_C = 500 mAdc)	2N242		30	120	
(V_{CE} = 1 Vdc, I_C = 200 mAdc)	2N307		20	—	
	2N307A		30	—	
Common Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(V_{CE} = 12 V, I_C = 0.5 A)	2N242		5.0	—	
	2N307A		3.5	—	
(V_{CE} = 6 V, I_C = 1 A)	2N307		3.0	—	
Power Gain		G_e			dB
(I_C = 0.5 A, V_{CE} = -14 V, R_L = 30 Ω, R_g = 10 Ω)	2N242		30		

2N277 (GERMANIUM)
2N278
2N173
2N1099



CASE 5
(TO-36)

PNP germanium power transistors for general purpose power amplifier and switching applications. Power and temperature ratings exceed EIA registration.

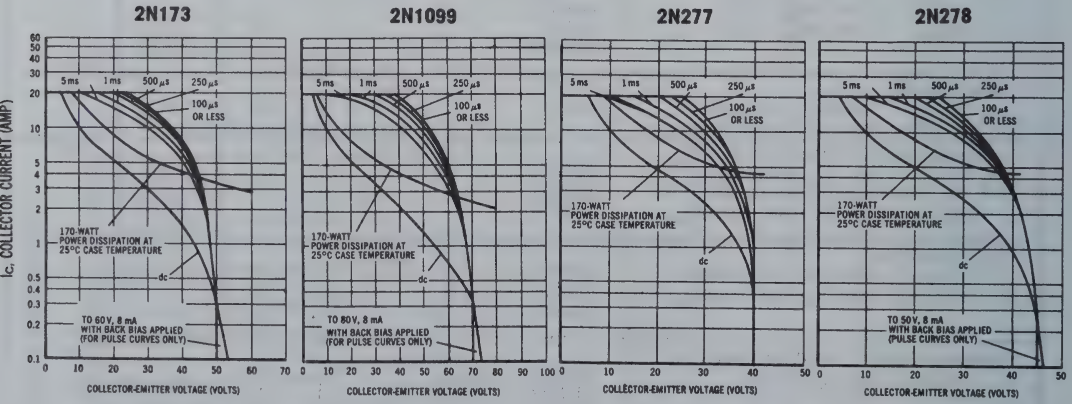
MAXIMUM RATINGS

Rating	Symbol	2N277	2N278	2N173	2N1099	Unit
Collector-Base Voltage	V_{CB}	40	50	60	80	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	40	Vdc
Emitter Current-Continuous	I_E	15				Adc
Base Current	I_B	4.0				Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	170 2.0				Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

SAFE OPERATING AREAS



2N173 2N1099 2N277 2N278

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

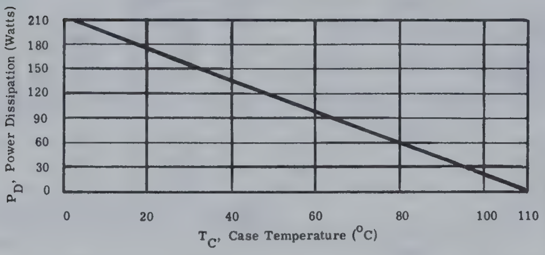
2N277, 2N278, 2N173, 2N1099 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current V_{CBO} = 2 V		I_{CBO}	—	100	—	μA
Collector-Base Cutoff Current V_{EB} = 1.5 V, V_{CB} = 40 V	2N277	I_{CBX}	—	2.0	8.0	mA
50	2N278		—	2.0	8.0	
60	2N173		—	2.0	8.0	
80	2N1099		—	2.0	8.0	
Emitter-Base Cutoff Current V_{EBO} = 20 V	2N277	I_{EBO}	—	1.0	8.0	mA
30	2N278		—	1.0	8.0	
40	2N173		—	1.0	8.0	
40	2N1099		—	1.0	8.0	
Collector-Base Cutoff Current V_{CBO} = 40 V, 71°C	2N277	I_{CBO}	—	—	15	mA
50	2N278		—	—	15	
60	2N173		—	—	15	
80	2N1099		—	—	15	
Collector-Emitter Voltage I_C = 300 mA, V_{EB} = 0	2N277	BV_{CES}*	40	—	—	Vdc
	2N278		45	—	—	
	2N173		50	—	—	
	2N1099		70	—	—	
Collector-Emitter Voltage I_C = 1 Amp, I_B = 0	2N277	BV_{CEO}*	25	—	—	Vdc
	2N278		30	—	—	
	2N173		45	—	—	
	2N1099		55	—	—	
Floating Potential I_E = 0, V_{CB} = 40 V	2N277	V_{fl}	—	0.15	1.0	volt
50	2N278		—	0.15	1.0	
60	2N173		—	0.15	1.0	
80	2N1099		—	0.15	1.0	
Current Gain I_C = 5 Amp, V_{CB} = 2 V		h_{FE}	35	—	70	—
I_C = 12 Amp, V_{CB} = 2 V			—	25	—	
Base-Emitter Voltage I_C = 5 Amp, V_{CB} = 2 V	2N277	V_{BE}	—	0.65	—	Vdc
	2N278		—	0.65	—	
	2N173		—	0.65	—	
	2N1099		—	0.65	0.9	
Saturation Voltage I_C = 12 Amp, I_B = 2 Amp	2N277	$V_{CE(SAT)}$	—	0.3	—	Vdc
	2N278		—	0.3	1.0	
	2N173		—	0.3	1.0	
	2N1099		—	0.3	0.7	
Common-Emitter Current Amplification Cutoff Frequency I_C = 5 Amp, V_{CE} = 6 V		$f_{\alpha e}$	0.3	10	—	kHz
Rise Time "on" I_C = 12 Adc, I_B = 2 Adc, V_{CE} = 12 V		t_r	—	15	—	μs
Fall Time "off" I_C = 0, V_{EB} = 6 V, R_{EB} = 10 Ohms		t_f	—	15	—	μs

* To avoid excessive heating of the collector junction, perform these tests with the sweep method.

POWER-TEMPERATURE DERATING CURVE

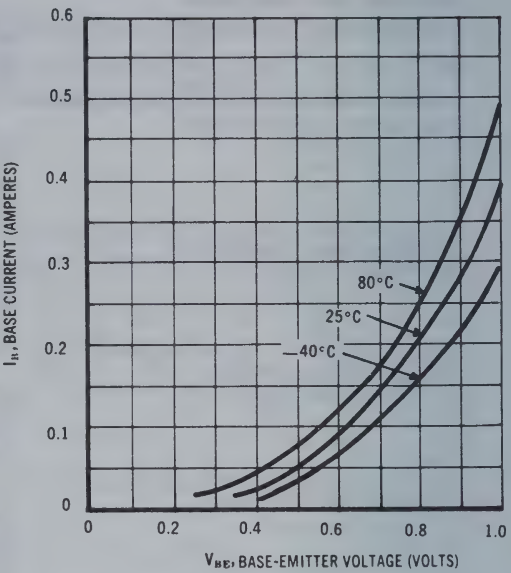


The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

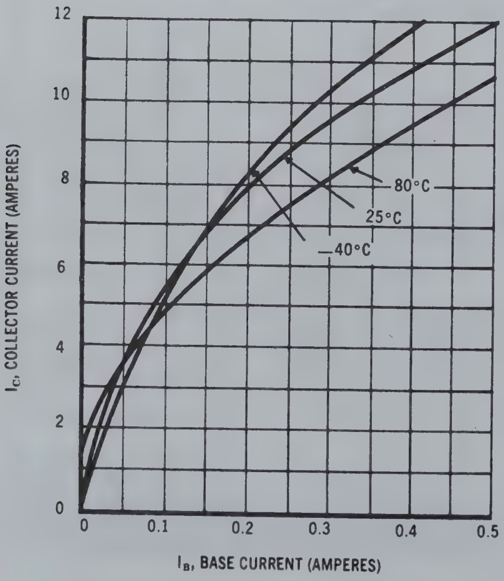
This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110° - T_C}{0.5}$$

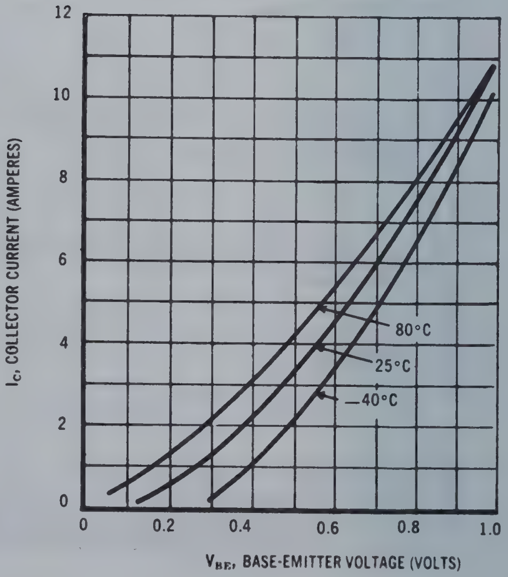
INPUT CHARACTERISTICS



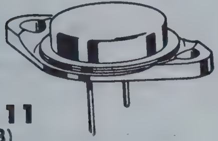
CURRENT TRANSFER CHARACTERISTICS



TRANSCONDUCTANCE CHARACTERISTICS



2N297A (GERMANIUM)



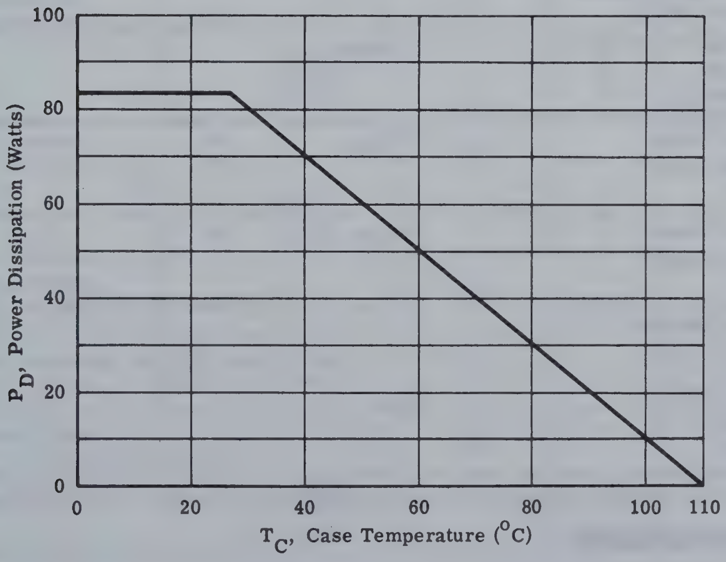
CASE 11
(TO-3)

PNP germanium power transistor for military and industrial power switching and amplifier applications. Operating temperature range and collector dissipation rating exceeds military specifications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Emitter Current	I_E	5.0	Amp
Operating Temperature Range	T_J	−65 to +110	°C
Collector Dissipation at 25°C Case Temperature (θ_{JC} = 1°C/W max)	P_D	85	Watts

POWER-TEMPERATURE DERATING CURVE



2N297 A (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Maximum	Unit
DC Current Transfer Ratio V_{CE} = 2 V I_C = 0.5 Adc	h_{FE}	40	100	—
DC Current Transfer Ratio V_{CE} = 2 V I_C = 2.0 Adc	h_{FE}	20	—	—
Small-Signal Current Transfer Ratio Cutoff Frequency V_{CE} = 14 Vdc I_C = 0.5 Amp	$f_{\alpha e}$	5.0	—	kHz
Emitter-Base Cutoff Current V_{EB} = 40 Vdc I_C = 0	I_{EBO}	—	3.0	mAdc
Collector-Base Cutoff Current V_{CB} = 2 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector-Base Cutoff Current V_{CB} = 60 Vdc I_E = 0	I_{CBO}	—	3.0	mAdc
Base Current V_{CE} = 2 Vdc I_C = 0.5 Adc	I_B	5.0	12.5	mAdc
Base Current V_{CE} = 2 Vdc I_C = 2 Adc	I_B	—	100	mAdc
Emitter-Base Voltage V_{CE} = 2 Vdc I_C = 2 Adc	V_{EB}	—	1.5	Vdc
Floating Potential V_{CB} = 60 Vdc (Voltmeter input resistance = 10 Megohm min)	V_{fl}		0.18	Vdc
Collector-Emitter Saturation Voltage I_C = 2 Adc I_B = 200 mAdc	$V_{CE(SAT)}$		1.0	Vdc
Collector-Emitter Voltage I_C = 300 mAdc I_B = 0	BV_{CEO}	40	—	Vdc
Collector-Emitter Voltage I_C = 300 mAdc V_{EB} = 0	BV_{CES}	50	—	Vdc
High-Temperature Operation T_C = +71°C min Collector Cutoff Current V_{CB} = 30 Vdc I_E = 0	I_{CBO}	—	6.0	mAdc

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2N307 (GERMANIUM)
2N307 A

For Specifications, See 2N242 Data.

2N319 thru 2N321 (Germanium)

CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for audio amplifier and low-frequency switching applications.

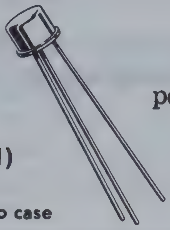
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J, T_{stg}	-65 to + 100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -25 Vdc, I_E = 0	I_{CBO}	-	16	μAdc
Emitter Cutoff Current V_{EB} = - 15 Vdc, I_C = 0	I_{EBO}	-	10	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	BV_{CER}	20	-	Vdc
DC Current Gain I_C = 20 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N319		25	42	-
2N320		34	65	
2N321		53	121	
DC Current Gain I_C = 100 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N319		23	-	-
2N320		30	-	
2N321		47	-	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}	180	320	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	-	35	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			
2N319		1.0	-	MHz
2N320		1.5	-	
2N321		2.0	-	

2N322 thru 2N324 (GERMANIUM)
2N508



CASE 31(1)
(TO-5)
Base connected to case

PNP germanium transistors for audio driver and low power output service in entertainment equipment.

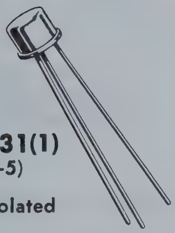
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	18	Vdc
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J, T_{stg}	-65 to + 100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -16 Vdc, I_E = 0	I_{CBO}	—	16	μAdc
Emitter Cutoff Current V_{EB} = -3 Vdc, I_C = 0	I_{EBO}	—	16	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 5 K	BV_{CER}	18	—	Vdc
DC Current Gain V_{CE} = -1 Vdc, I_C = 20 mAdc	h_{FE}			—
2N322		34	65	
2N323		53	121	
2N324		72	198	
2N508		99	198	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}	180	320	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	—	35	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			MHz
2N322		1.0	—	
2N323		1.5	—	
2N324		2.0	—	
2N508		2.5	—	

2N331 (Germanium)



CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for audio range amplifier and switching service in military equipment. Have collector dissipation and storage temperature ratings significantly higher than those of the military specification (see maximum ratings table below).

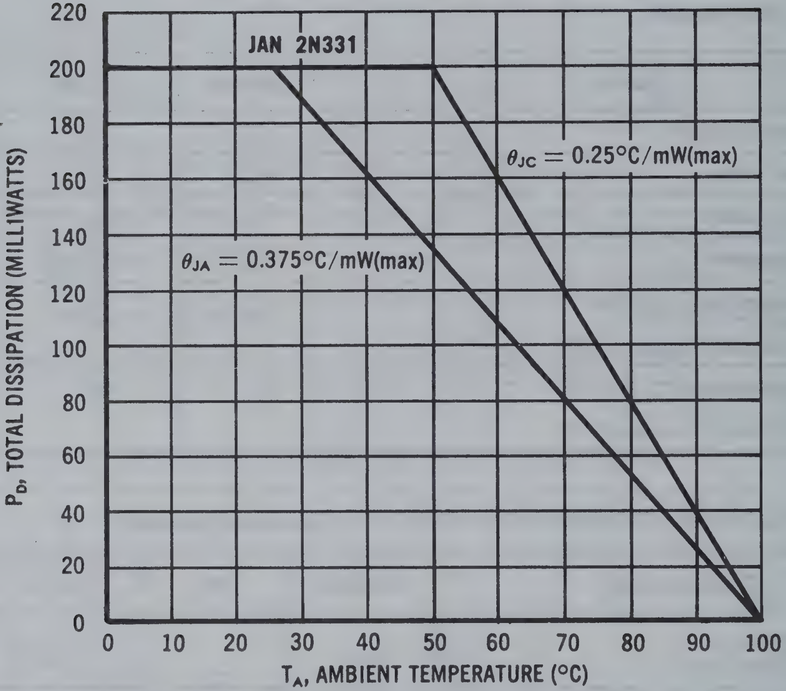
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Volts
Emitter-Base Voltage	V_{EB}	12	Volts
Storage Temperature	T_{stg}	-65 to + 85	°C
Storage Temperature	T_{stg}	-65 to + 100	°C
Collector Dissipation at T_A = 25°C (MIL-S-19500/4C (Derate 1.25 mW/°C above 25°C)	P_D	75	mW
Collector Dissipation at T_A = 25°C (JAN 2N331) (Derate 2.67 mW/°C above 25°C)	P_D	200	mW

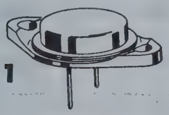
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Emitter Cutoff Current (V_{EB} = -12 Vdc, I_C = 0)	I_{EBO}	—	10	μAdc
Collector Cutoff Current (V_{CB} = -30 Vdc, I_E = 0)	I_{CBO}	—	10	μAdc
Small-Signal Open-Circuit Output Admittance (V_{CB} = -6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	h_{ob}	—	1.0	μmho
Small-Signal Short-Circuit Input Impedance (V_{CB} = -6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	h_{ib}	—	50	Ohms
Small-Signal Short-Circuit Forward-Current Transfer Ratio (V_{CE} = -6 Vdc, I_C = 1.0 mAdc, f = 1 kHz)	h_{fe}	30	70	—
Small-Signal Short-Circuit Forward-Current Transfer Ratio Cutoff Frequency (V_{CB} = -6 Vdc, I_E = 1 mAdc)	$f_{\alpha b}$	0.4	—	MHz
Output Capacitance (V_{CB} = -6 Vdc, I_E = 1 mAdc)	C_{ob}	—	50	pF
Noise Figure (V_{CB} = -6 Vdc, I_E = 1 mAdc, R_S = 1000, ohms, f = 1 kHz , f=Δ1 Hz)	NF	—	20	dB

POWER-TEMPERATURE DERATING CURVE



2N350A (GERMANIUM)
2N351A
2N376A



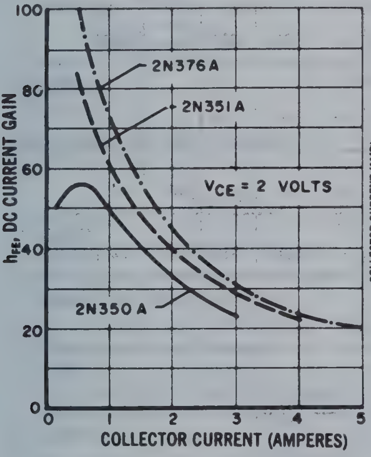
CASE 11
(TO-3)

PNP germanium power transistors for economical power switching applications and for power amplifiers requiring up to 4 watts of output power at relatively low distortion.

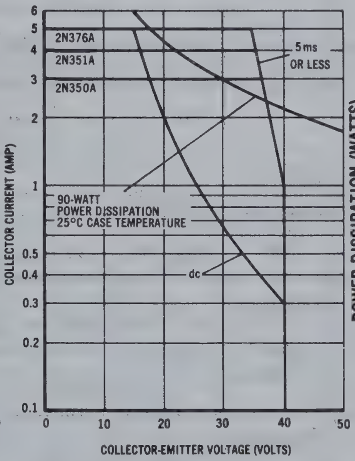
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector Dissipation at 25°C mounting base temperature	P_D	90	Watts
Collector Junction Temperature	T_J	−65 to +100	°C
Thermal Resistance (Junction to Case)	θ_{JC}	0.8	°C/W

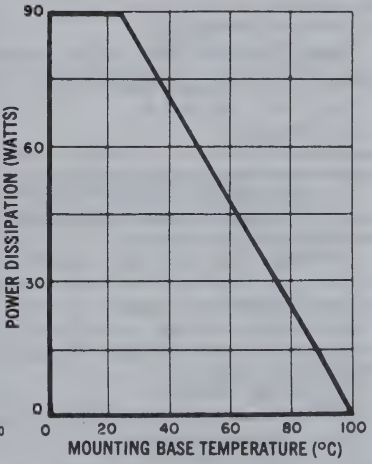
CURRENT GAIN versus COLLECTOR CURRENT (COMMON EMITTER)



SAFE OPERATING AREAS



POWER TEMPERATURE DERATING CURVE



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N350A, 2N351A, 2N376A (continued)

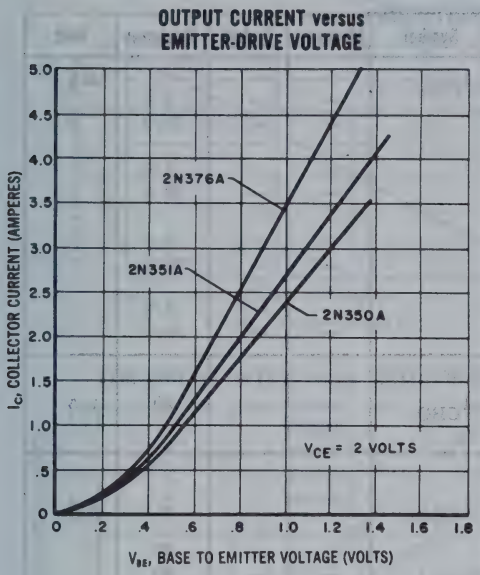
ELECTRICAL CHARACTERISTICS (at mounting base temperature 25°C ± 3°C.)

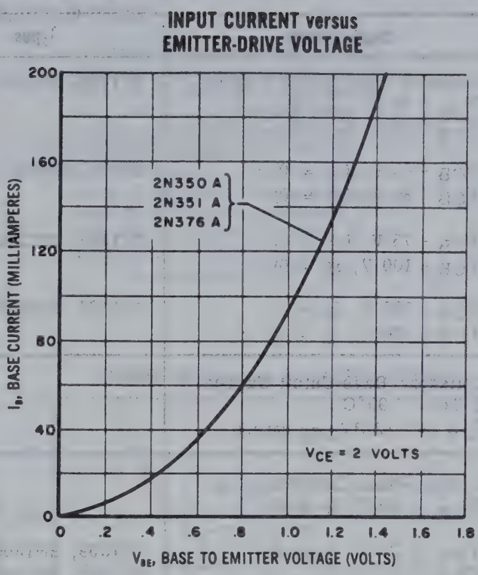
GENERAL	Symbol	Minimum	Typical	Maximum	Unit
Collector Cutoff Current V_{CB} = 30 V V_{CB} = 2 V V_{CB} = 30 V, T = 100°C	I_{CBO}	— — —	— 50 —	3.0 — 30	mA μA mA
Emitter Cutoff Current V_{EB} = 10 V	I_{EBO}	—	—	2.0	mA
Collector Breakdown Voltage I_C = 1 A (R_{BE} = 10 Ω) I_C = 330 mA, R_{BE} = 0 (This test should be made under dynamic conditions only)	BV_{CES}	40	—	—	Vdc

ELECTRICAL CHARACTERISTICS (at mounting base temperature 25°C ± 3°C.)

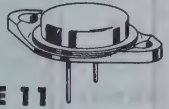
COMMON EMITTER		2N350A			2N351A			2N376A			Unit
	Sym	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Power Gain (± 0.5 db) P_{out} = 4 Watts, V_{CE} = 12 V, I_C = 0.7 A, f = 1 kHz	G_{PE}	30	—	33	32	—	35	34	—	37	dB
Total Harmonic Distortion under same conditions as power gain		—	—	7.0	—	—	7.0	—	—	7.0	%
DC Forward Current Gain V_{CE} = 2 V, I_C = 0.7 A	h_{FE}	20	—	60	25	—	90	35	—	120	
Current Gain Frequency Cutoff V_{CE} = 12 V, I_C = 0.7 A, f = 1 kHz ref	$f_{\alpha e}$	5.0	—	—	5.0	—	—	5.0	—	—	kHz
Small-Signal Forward Current Gain f = 1 kHz, V_{CE} = 2 V, I_C = 0.7 A	h_{fe}	—	30	—	—	45	—	—	60	—	
Small-Signal Input Impedance f = 1 kHz, V_{CE} = 2 V, I_C = 0.7 A	h_{ie}	5.0	—	17	6.0	—	20	7.0	—	25	Ohms
Collector Saturation Voltage I_C = 3 A, I_B = 300 mA	$V_{CE(SAT)}$	—	0.8	1.75	—	—	—	—	—	—	Vdc
Base-Emitter Voltage I_C = 3 A, I_B = 300 mA	V_{BE}	—	1.0	2.00	—	—	—	—	—	—	Vdc
Collector Saturation Voltage I_C = 4 A, I_B = 400 mA	$V_{CE(SAT)}$	—	—	—	—	0.8	1.75	—	—	—	Vdc
Base-Emitter Voltage I_C = 4 A, I_B = 400 mA	V_{BE}	—	—	—	—	1.0	2.00	—	—	—	Vdc
Collector Saturation Voltage I_C = 5 A, I_B = 500 mA	$V_{CE(SAT)}$	—	—	—	—	—	—	—	0.8	1.75	Vdc
Base-Emitter Voltage I_C = 5 A, I_B = 500 mA	V_{BE}	—	—	—	—	—	—	—	1.0	2.00	Vdc

2N350A, 2N351A, 2N376A (continued)


OUTPUT CURRENT versus EMITTER-DRIVE VOLTAGE


INPUT CURRENT versus EMITTER-DRIVE VOLTAGE

2N375 (GERMANIUM)
2N618
2N1359
2N1360
2N1362 thru 2N1365


CASE 11
(TO-3)

PNP germanium power transistors for general purpose switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N1359 2N1360	2N375 2N618	2N1362 2N1363	2N1364 2N1365	Unit
Collector-Emitter Voltage	V_{CES}	40	60	75	100	Vdc
Collector-Base Voltage	V_{CB}	50	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	25	40	50	60	Vdc
Collector Current-Continuous Peak	I_C	3.0 10				Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	106 1.25				Watts W/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110				^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^oC/W$

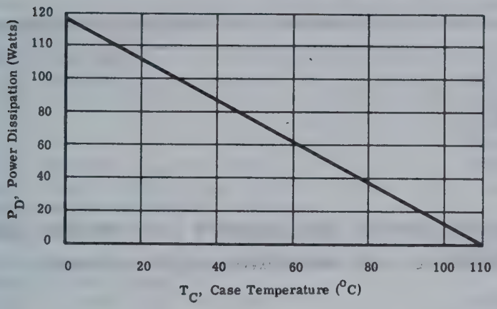
2N375, 2N618, 2N1359, 2N1360, 2N1362 thru 2N1365 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Types	Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current	2N1359, 2N1360	I_{CBO}				mA
(V_{CB} = 40 V, I_E = 0)			--	--	3.0	
(V_{CB} = 50 V, I_E = 0)			--	--	20.0	
(V_{CB} = 60 V, I_E = 0)	2N375, 2N618		--	--	3.0	
(V_{CB} = 80 V, I_E = 0)			--	--	20.0	
(V_{CB} = 75 V, I_E = 0)	2N1362, 2N1363		--	--	3.0	
(V_{CB} = 100 V, I_E = 0)			--	--	20.0	
(V_{CB} = 100 V, I_E = 0)	2N1364, 2N1365		--	--	3.0	
(V_{CB} = 120 V, I_E = 0)			--	--	20.0	
Collector-Base Cutoff Current at Tc = +90°C V_{CB} = 1/2 BV_{CES} rating		I_{CBO}	--	--	20	mA
Emitter-Base Cutoff Current (V_{EB} = 12 V, I_C = 0)		I_{EBO}	--	--	0.5	mA
(V_{EB} = 25 V, I_C = 0)	2N1359, 2N1360		--	--	20	
(V_{EB} = 50 V, I_C = 0)	2N1362, 2N1363		--	--	20	
(V_{EB} = 60 V, I_C = 0)	2N1364, 2N1365		--	--	20	
Collector-Emitter Breakdown Voltage						Vdc
I_C = 500 mA, V_{EB} = 0)	2N1359, 2N1360	BV_{CES}	40	--	--	
	2N375, 2N618		60	--	--	
	2N1362, 2N1363		75	--	--	
	2N1364, 2N1365		100	--	--	
DC Current Transfer Ratio		h_{FE}				--
(V_{CE} = 4 V, I_C = 1.0A)	2N1359, 375, 1362, 64		35	55	90	
	2N1360, 618, 1363, 65		60	90	140	
(V_{CE} = 4 V, I_C = 1.0A)	2N1359, 375, 1362, 64		15	22	--	
	2N1360, 618, 1363, 65		20	35	--	
Transconductance						mhos
(V_{CE} = 4 V, I_C = 1.0A)	2N375	g_{FE}	0.8	1.25	2.2	
	2N618		1.0	1.6	2.5	
	2N1359, 2N1362, 2N1364		0.8	1.25	--	
	2N1360, 2N1363, 2N1365		1.0	1.6	--	
Frequency Cutoff		$f_{\alpha e}$				kHz
(V_{CE} = 4 V, I_C = 1 A)	2N375		5.0	8.5	--	
(V_{CE} = 4 V, I_C = 1 A)	2N618		5.0	8.5	--	
(V_{CE} = 4 V, I_C = 3 A)	2N1359, 2N1362, 2N1364		7.0	10	--	
(V_{CE} = 4 V, I_C = 3 A)	2N1360, 2N1363, 2N1365		5.0	8.5	--	
Collector Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 2.0 A, I_B = 200mA)	2N1359, 375, 1362, 64		--	0.4	1.0	
	2N1360, 618, 1363, 65		--	0.3	0.8	
Base-Emitter Drive Voltage		V_{BE}				Vdc
(I_C = 2.0A, I_B = 200 mA)	2N1359, 375, 1362, 64		--	0.7	--	
	2N1360, 618, 1363, 65		--	0.6	--	
Collector-Emitter Punch-Through Voltage		V_{EBF}				Vdc
(V_{CB} = 50 V, I_C = 0)	2N1359, 2N1360		--	--	1.25	
(V_{CB} = 100 V, I_C = 0)	2N1362, 2N1363		--	--	1.25	
(V_{CB} = 120 V, I_C = 0)	2N1364, 2N1365		--	--	1.25	

2N375 (continued)

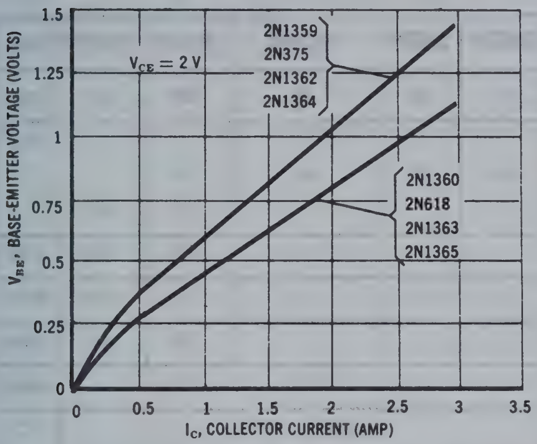
POWER-TEMPERATURE DERATING CURVE



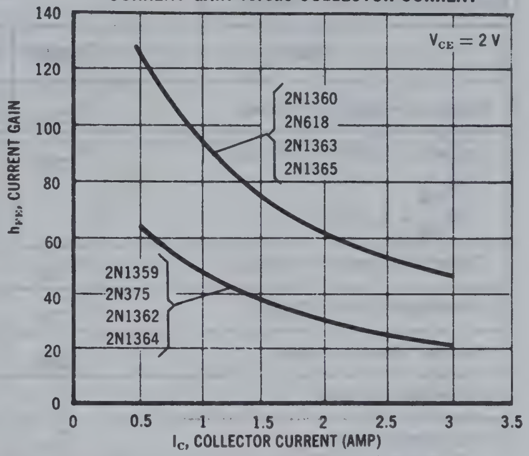
The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For d. c. or frequencies below 25 cps the transistor must be operated within the constant $P_D = V_c \times I_c$ hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^\circ - T_c}{0.8}$$

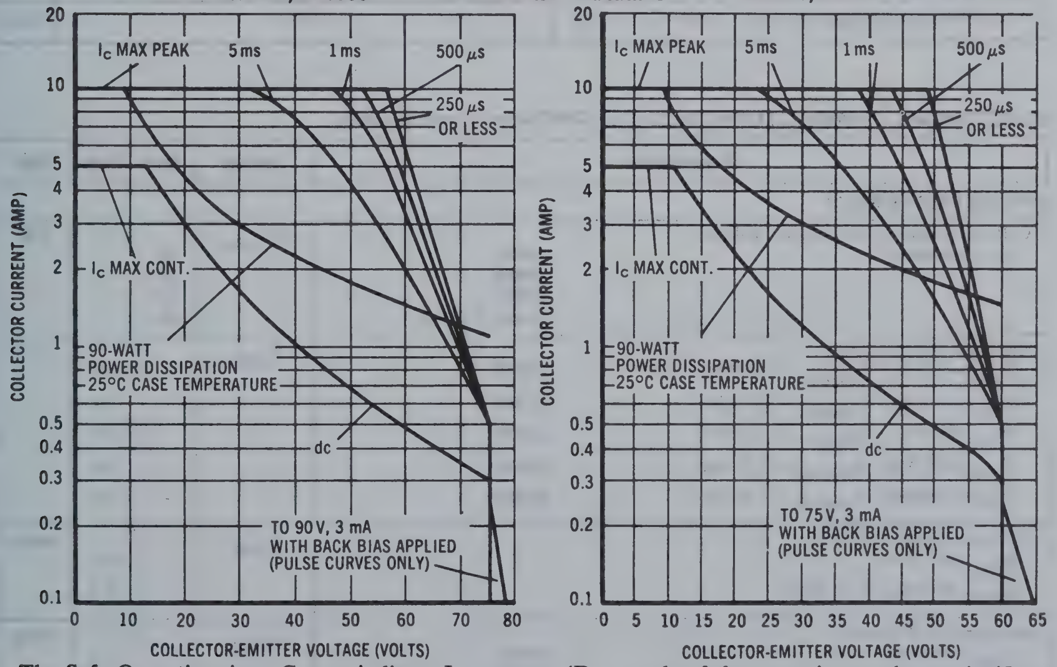
BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT



CURRENT GAIN versus COLLECTOR CURRENT



SAFE OPERATING AREAS



2N1362, 2N1363

2N375, 2N618

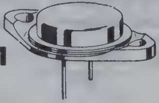
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N376A (GERMANIUM)

For Specifications, See 2N350A Data.

2N378 thru 2N380 (GERMANIUM)

2N459,A



CASE 11
(TO-3)

PNP germanium power transistors for general purpose power amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N378	2N379	2N380	2N459	2N459A	Unit
Collector-Emitter Voltage	V_{CEO}	20	40	30	60	60	Vdc
Collector-Emitter Voltage	V_{CEX}						Vdc
(V_{BE} = 1.5 V)		40	80	60	-	-	
(V_{BE} = 1.0 V)		-	-	-	105	105	
Collector-Emitter Voltage	V_{CES}	-	-	-	70	70	Vdc
Collector-Base Voltage	V_{CB}	-	-	-	-	105	Vdc
Emitter-Base Voltage	V_{EB}	-	-	-	10	25	Vdc
Collector Current	I_C	5.0					Adc
Operating Junction Temperature Range	T_J	-65 to +110					°C
Total Device Dissipation @ T_C = 25°C	P_D	106					Watts

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 100 mAdc)	2N378		20	-	
	2N379		40	-	
	2N380		30	-	
	2N459, 2N459A		60	-	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N378		-	10	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N380		-	10	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N379		-	10	
(V_{CE} = 105 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N459		-	10	
(V_{CE} = 105 Vdc, $V_{BE(off)}$ = 1.0 Vdc)	2N459A		-	10	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 25 Vdc)			-	0.5	
(V_{CB} = 25 Vdc, T_C = 85°C)			-	7.5	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 10 Vdc)	2N380		-	1.5	
	2N459		-	2.0	
(V_{BE} = 25 Vdc)	2N459A		-	2.0	

2N378, thru 2N380 2N459, 2N459 A (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N378		40	80	
	2N379, 2N459		20	70	
	2N380		30	70	
	2N459A		40	70	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N459A		20	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 2.0 Adc, I_B = 0.2 Adc)	2N378-2N380, 2N459		-	1.0	
	2N459A		-	0.3	
Base-Emitter Voltage		$V_{BE(on)}$			Vdc
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N378		-	1.6	
	2N379, 2N459, 2N459A		-	1.3	
	2N380		-	1.0	
DYNAMIC CHARACTERISTICS					
Common-Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	2N378-2N380, 2N459		5.0	-	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N459A		5.0	-	

2N381 thru 2N383 (GERMANIUM)

2N2171

CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for small-signal audio amplifiers, Class B push-pull output stages and medium-speed switching circuits.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Volts
Collector-Emitter Voltage (R_{BE} = 10K)	V_{CER}	25	Volts
Emitter-Base Voltage	V_{EB}	20	Volts
Collector Current	I_C	400	mA
Junction Temperature	T_J	-65 to +100	°C
Collector Dissipation	P_D		
T_A = 25°C		225	mW
derate		3.0	mW/°C
T_C = 25°C		500	mW
derate		6.7	mW/°C

ELECTRICAL CHARACTERISTICS (T$_C$ = 25°C unless otherwise noted)

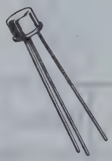
Characteristics		Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = -25 Vdc)		I_{CBO}	- - -	6.0	10	µAdc
Emitter-Base cutoff Current (V_{EB} = -20 Vdc)		I_{EBO}	- - -	5.0	10	µAdc
Collector-Emitter Voltage (I_C = 500 µAdc, R_{BE} = 10K)		BV_{CER}	25	- - -	- - -	Vdc
Collector-Emitter Voltage (I_C = 50 µAdc, V_{BE} = 1.0 Vdc)	2N381	BV_{CER}	- - -	50	- - -	Vdc
	2N382, 2N383, 2N2171		- - -	45	- - -	
DC Current Gain (I_C = 20 mAdc, V_{CE} = -1.0 Vdc)	2N381	h_{FE}	35	- - -	65	- - -
	2N382		60	- - -	95	
	2N383		75	- - -	120	
	2N2171		110	- - -	250	
(I_C = 100 mAdc, V_{CE} = -1.0 Vdc)	2N381		30	- - -	- - -	
	2N382		50	- - -	- - -	
	2N383		65	- - -	- - -	
	2N2171		90	- - -	- - -	

ELECTRICAL CHARACTERISTICS (continued)

Characteristics	Symbol	Min	Typical	Max	Unit
Small Signal Current Gain (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)	h_{fe}				- - -
2N381		35	60	85	
2N382		70	90	135	
2N383		90	115	155	
2N2171		120	210	310	
Voltage Feedback Ratio (I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	h_{re}				$X10^{-3}$
2N381		- - -	0.66	- - -	
2N382		- - -	0.69	- - -	
2N383		- - -	0.72	- - -	
2N2171		- - -	0.75	- - -	
Input Impedance (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)	h_{ie}				ohms
2N381		- - -	300	- - -	
2N382		- - -	450	- - -	
2N382		- - -	550	- - -	
2N2171		- - -	850	- - -	
Output Admittance (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)	h_{oe}				µmhos
2N381		- - -	420	- - -	
2N382		- - -	400	- - -	
2N383		- - -	380	- - -	
2N2171		- - -	500	- - -	
Transducer Gain	G_T				dB
(R_g = 300 Ω , R_L = 500 Ω) 2N381		- - -	36	- - -	
(R_g = 450 Ω , R_L = 500 Ω) 2N382		- - -	38	- - -	
(R_g = 550 Ω , R_L = 500 Ω) 2N383		- - -	39.5	- - -	
(R_g = 785 Ω , R_L = 500 Ω) 2N2171		- - -	42.5	- - -	
Output Capacitance (I_C = 1 mA, V_{CB} = -6V)	C_{ob}	- - -	20	- - -	pF
Noise Figure (I_C = 1 mA, V_{CE} = -6V, R_g = 1 kc, f = 1 kHz)	NF				dB
2N381		- - -	6.0	- - -	
2N382		- - -	5.5	- - -	
2N383		- - -	5.0	- - -	
2N2171		- - -	3.5	- - -	
Cutoff Frequency (I_C = 1 mA, V_{CB} = -6V)	$f_{\alpha b}$				MHz
2N381		- - -	3.0	- - -	
2N382		- - -	4.0	- - -	
2N383		- - -	5.0	- - -	
2N2171		- - -	7.5	- - -	

2N398, 2N398 A (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated



PNP germanium transistor for high-voltage, audio-frequency applications.

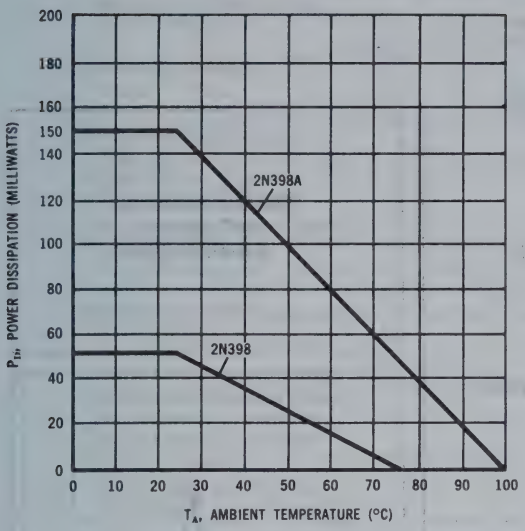
MAXIMUM RATINGS

Rating	Symbol	2N398A	2N398	Unit
Collector-Base Voltage	V_{CB}	105	105	Vdc
Collector-Emitter Voltage	V_{CEO}	105	105	Vdc
Emitter-Base Voltage	V_{EB}	50	50	Vdc
DC Collector Current	I_C	200	100	mA
Emitter Current	I_E	200	100	mA
Junction Temperature	T_J	-65 to +100	-65 to +85	°C
Storage Temperature	T_{stg}	-65 to +100	-65 to +85	°C
Collector Dissipation @ 25°C	P_D	150	50	mW
Thermal Resistance, Junction to Ambient	$\theta_{JA\ max}$	0.5	1.2	°C/mW

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

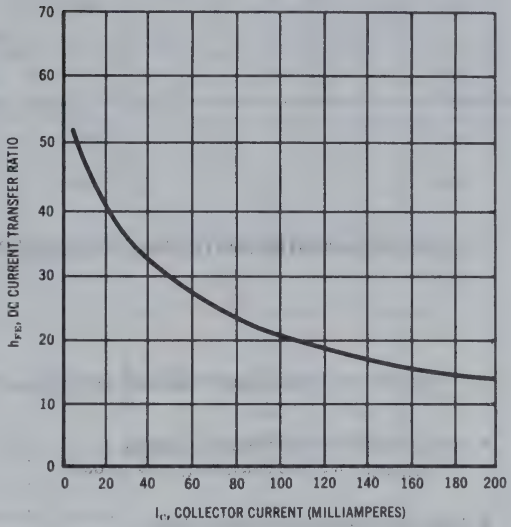
Characteristics	Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 105 V, I_B = 0)	I_{CBO}	-	12.0	50	μA
Collector-Base Cutoff Current (V_{CB} = 2.5 V, I_B = 0)	I_{CBO}	-	5.0	14	μA
Emitter-Base Cutoff Current (V_{EB} = 50 V, I_C = 0)	I_{EBO}	-	3.0	50	μA
Collector-Emitter Saturation Voltage (I_C = 5 mAdc; I_B = 0.25 mAdc)	$V_{CE\ (SAT)}$	-	0.11	0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 5 mAdc; I_B = 0.25 mAdc)	$V_{BE\ (SAT)}$	-	0.22	0.40	Vdc
DC Current Transfor Ratio (I_C = 5 mAdc; V_{CE} = 0.35 Vdc)	h_{FE}	20	65	-	-
DC Collector-Emitter Punch-Through Voltage (V_{CB} necessary to obtain V_{EB} of -1 V max, using instrument with Z_{in} > 11 megohm to measure V_{BE})	V_{PT}	105	160	-	Vdc
Small-Signal Short-Circuit, Forward Current Transfer Ratio Cutoff Frequency (V_{CB} = 6 Vdc; I_E = 1 mAdc)	$f_{\alpha b}$	-	1.0	-	MHz

POWER — TEMPERATURE DERATING CURVE



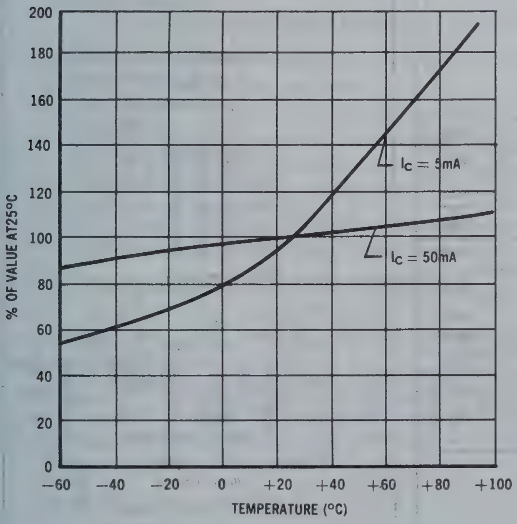
DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT

$V_{CE} = 0.35V$



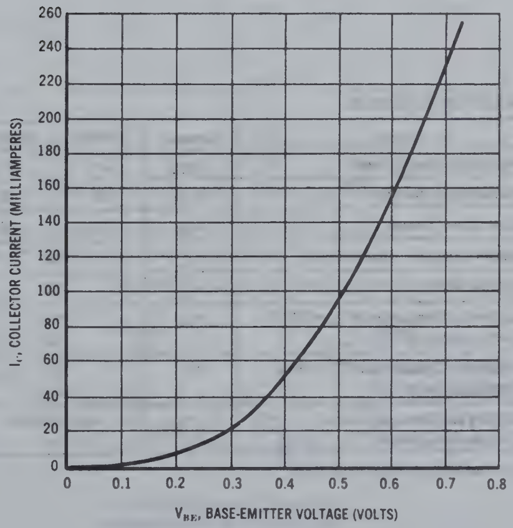
LARGE SIGNAL CURRENT GAIN (H_{FE}) versus TEMPERATURE

(Normalized to 25°C Value; $V_{CE} = 0.35V$)



OUTPUT CURRENT versus BASE-DRIVE VOLTAGE

($V_{CE} = -1$ V)



2N404 (GERMANIUM)
2N404A

PNP GERMANIUM SWITCHING TRANSISTORS

. . . designed for medium-speed saturated switching applications.

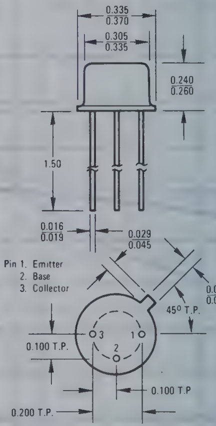
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.2 Vdc (Max) @ I_C = 24 mAdc
- High Emitter-Base Breakdown Voltage —
  BV_{EBO} = 12 Vdc (Min) @ I_E = 20 μAdc — 2N404
  = 25 Vdc (Min) @ I_E = 20 μAdc — 2N404A

PNP GERMANIUM SWITCHING TRANSISTORS

*MAXIMUM RATINGS

Rating	Symbol	2N404	2N404A	Unit
Collector-Emitter Voltage	V_{CES}	24	35	Vdc
Collector-Base Voltage	V_{CB}	25	40	Vdc
Emitter-Base Voltage	V_{EB}	12	25	Vdc
Collector Current — Continuous	I_C	150		mAdc
Emitter Current	I_E	100		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0		mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0		mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		^oC

*Indicates JEDEC Registered Data.


0.335
0.370
0.305
0.335
0.240
0.260
1.50
0.016
0.019
0.029
0.045
Pin 1. Emitter
2. Base
3. Collector
0.028
0.034
45° T.P.
0.100 T.P.
3
1
2
0.100 T.P
0.200 T.P.

Weight ≈ 1.15 gram

All JEDEC TO-5 dimensions and notes apply.

CASE 31 (1)
TO-5
Collector Connected to Case

2N404, 2N404A (continued)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 20 µAdc, I_E = 0)	2N404 2N404A	BV_{CBO}	25 40	– –	– –	Vdc
Emitter-Base Breakdown Voltage (I_E = 20 µAdc, I_C = 0)	2N404 2N404A	BV_{EBO}	12 25	– –	– –	Vdc
Punch-Through Voltage(1) (V_{EBfl} = 1.0 Vdc)	2N404 2N404A	V_{pt}	24 35	– –	– –	Vdc
Emitter-Base Floating Potential (V_{CB} = 35 Vdc, I_E = 0)	2N404A	V_{EBfl}	–	–	1.0	Vdc
Collector Cutoff Current (V_{CB} = 12 Vdc, I_E = 0) (V_{CB} = 12 Vdc, I_E = 0, T_A = 80°C)		I_{CBO}	– –	0.8 20	5.0 90	µAdc
Emitter Cutoff Current (V_{EB} = 2.5 Vdc, I_C = 0)		I_{EBO}	–	0.5	2.5	µAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 12 mAdc, V_{CE} = 0.15 Vdc) (I_C = 24 mAdc, V_{CE} = 0.20 Vdc)		h_{FE}	30 24	80 90	– –	–
Collector-Emitter Saturation Voltage (I_C = 12 mAdc, I_B = 0.4 mAdc) (I_C = 24 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	– –	0.09 0.09	0.15 0.20	Vdc
Base-Emitter Voltage (I_C = 12 mAdc, I_B = 0.4 mAdc) (I_C = 24 mAdc, I_B = 1.0 mAdc)		V_{BE}	– –	0.27 0.30	0.35 0.40	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Alpha Cutoff Frequency (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc)		f_{hfb}	4.0	25	–	MHz
Output Capacitance (V_{CB} = 6.0 Vdc, I_E = 0, f = 1.0 MHz) (V_{CB} = 6.0 Vdc, I_E = 1.0 mAdc, f = 2.0 MHz)	2N404 2N404A	C_{ob}	– –	8.0 8.0	20 20	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)		h_{ie}	–	3.6	–	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)		h_{re}	–	8.0	–	$\times 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)		h_{fe}	–	135	–	–
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)		h_{oe}	–	50	–	µmhos
SWITCHING CHARACTERISTICS						
Delay Time (Figure 1)		t_d	–	0.07	–	µs
Rise Time (Figure 1)		t_r	–	0.12	–	µs
Storage Time (Figure 1)		t_s	–	0.20	–	µs
Fall Time (Figure 1)		t_f	–	0.10	–	µs
Stored Base Charge (Figure 2)		Q_{sb}	–	300	1400	pC

*Indicates JEDEC Registered Data.

(1) V_{pt} is determined by measuring the emitter-base floating potential V_{EBfl}, using a voltmeter with 11 megohms minimum input impedance. The collector-base voltage, V_{CB}, is increased until V_{EBfl} = -1.0 Vdc; this value of V_{CB} = (V_{pt} + 1).

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT

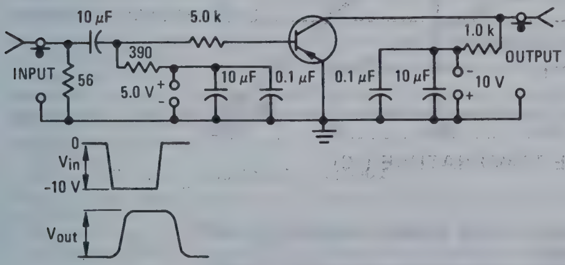
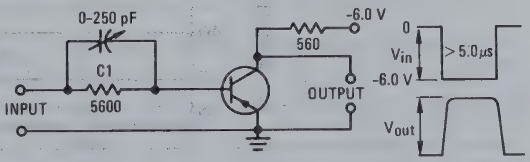


FIGURE 2 – STORED BASE CHARGE TEST CIRCUIT

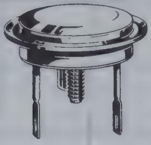


C1 is increased until the t_{off} time of the output waveform is decreased to 0.2 µs. Q_{sb} is then calculated by $Q_{sb} = C1\ V_{in}$.

NOTES:
1. Input pulse supplied by generator with following characteristics:
   - a. Output impedance: 50 Ohms
   - b. Repetition rate: 1.0 kHz
   - c. Rise and fall time: 20 ns Max
2. Waveforms monitored on scope with following characteristics:
   - a. Input resistance – 10 Megohms Min
   - b. Input capacitance – 15 pF Max
   - c. Rise time – 15 ns Max
3. All resistors ± 1.0% tolerance.

2N441 (GERMANIUM)
2N442
2N443

PNP germanium power transistors for power switching and amplifier applications. Power and temperature ratings exceed EIA registration.



CASE 5
(TO-36)

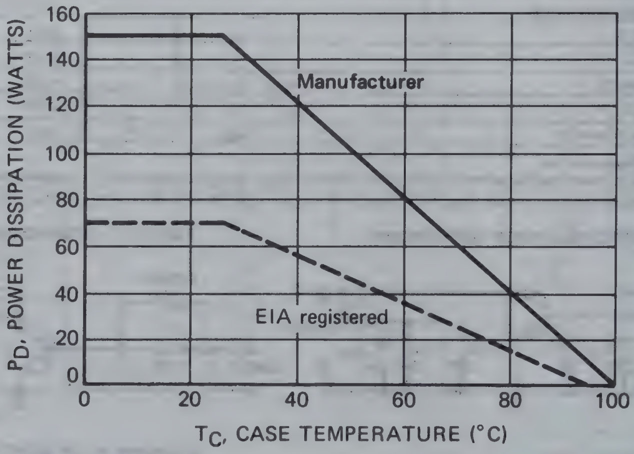
MAXIMUM RATINGS

Rating	Symbol	2N441	2N442	2N443	Unit
Collector-Emitter Voltage	V_{CES}	40	45	50	Vdc
Collector-Base Voltage	V_{CB}	40	50	60	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	Vdc
Base Current — Continuous	I_B	4.0			Adc
Emitter Current — Continuous	I_E	15			Adc
Total Device Dissipation @ T_C = 25°C	P_D	150			Watts
Operating Junction Temperature Range (EIA Registered)	T_J	-65 to +95			°C
Operating Junction Temperature Range	T_J	-65 to +100			°C

THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Case (EIA Registered)	θ_{JC}	1.0	°C/W
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor.

This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 100°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{100^\circ - T_C}{0.5}.$$

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 1.0 Adc, I_B = 0)	2N441	BV_{CEO}*	25	-	-	Vdc
	2N442		30	-	-	
	2N443		45	-	-	
Collector-Emitter Breakdown Voltage* (I_C = 300 mAdc, V_{BE} = 0)	2N441	BV_{CES}*	40	-	-	Vdc
	2N442		45	-	-	
	2N443		50	-	-	
Floating Potential (V_{CB} = 40 Vdc, I_E = 0)	2N441	V_{EBF}	-	-	1.0	Vdc
(V_{CB} = 50 Vdc, I_E = 0)	2N442		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N443		-	-	1.0	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	0.1	-	mAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N441		-	2.0	8.0	
(V_{CB} = 50 Vdc, I_E = 0)	2N442		-	2.0	8.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N443		-	2.0	8.0	
(V_{CB} = 40 Vdc, I_E = 0, T_B = 71°C)	2N441		-	-	15	
(V_{CB} = 50 Vdc, I_E = 0, T_B = 71°C)	2N442		-	-	15	
(V_{CB} = 50 Vdc, I_E = 0, T_B = 71°C)	2N443		-	-	15	
Emitter Cutoff Current (V_{BE} = 20 Vdc, I_C = 0)	2N441	I_{EBO}	-	1.0	8.0	mAdc
(V_{BE} = 30 Vdc, I_C = 0)	2N442		-	1.0	8.0	
(V_{BE} = 40 Vdc, I_C = 0)	2N443		-	1.0	8.0	
ON CHARACTERISTICS						
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	-	40	-
(I_C = 12 Adc, V_{CE} = 2.0 Vdc)			-	20	-	
Collector-Emitter Saturation Voltage (I_C = 12 Adc, I_B = 2.0 Adc)	2N441	$V_{CE(sat)}$	-	0.3	-	Vdc
	2N442		-	0.3	-	
	2N443		-	0.3	1.0	
Base-Emitter Voltage (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N441	V_{BE}	-	0.65	-	Vdc
	2N442		-	0.65	-	
	2N443		-	0.65	0.9	
DYNAMIC CHARACTERISTICS						
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)		$f_{\alpha e}$	-	10	-	kHz
SWITCHING CHARACTERISTICS						
Rise Time (V_{CE} = 12 Vdc, I_C = 12 Adc, I_B = 2.0 Adc)		t_r	-	15	-	µs
Fall Time (I_C = 0, V_{BE} = 6.0 Vdc, R_{BE} = 10 ohms)		t_f	-	15	-	µs

* Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

TYPICAL COMMON-EMITTER CHARACTERISTICS

FIGURE 2 – OUTPUT CHARACTERISTICS

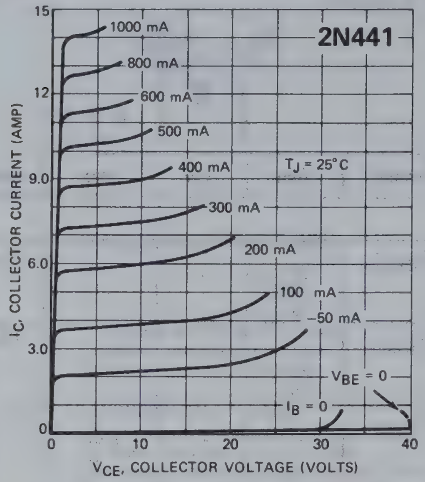


FIGURE 3 – OUTPUT CHARACTERISTICS

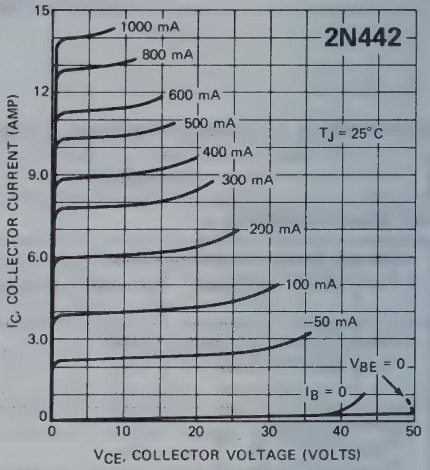


FIGURE 4 – OUTPUT CHARACTERISTICS

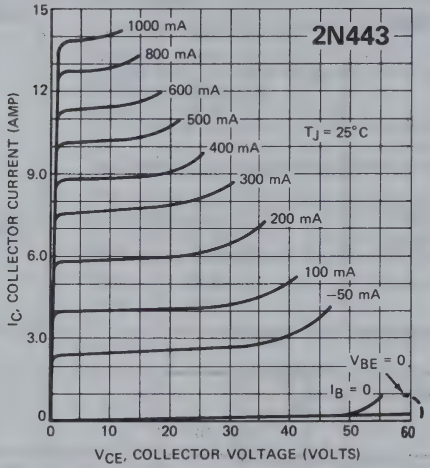


FIGURE 5 – INPUT CHARACTERISTICS

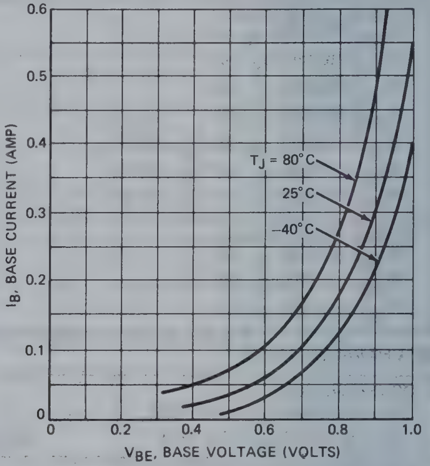


FIGURE 6 – DC CURRENT GAIN TRANSFER CHARACTERISTICS

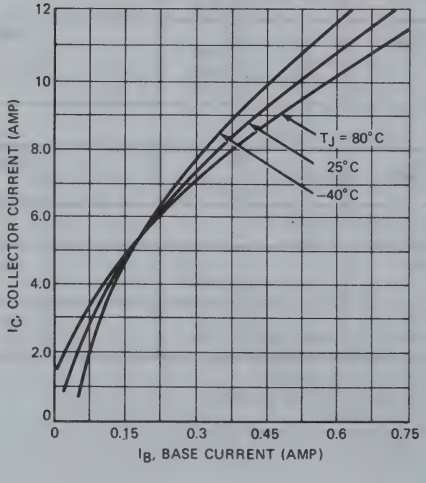
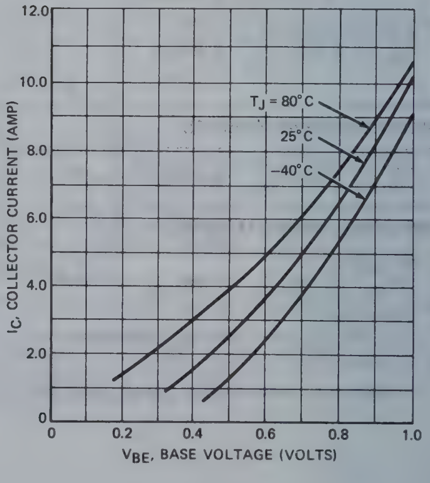


FIGURE 7 – TRANSCONDUCTANCE CHARACTERISTICS



2N456A (GERMANIUM)
2N457A
2N458A

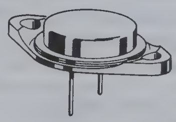
PNP GERMANIUM POWER TRANSISTORS

. . . designed for general-purpose power amplifier and switching applications.

- High DC Current Gain – h_{FE} = 30–90 @ I_C = 5.0 Adc
- Low Collector-Emitter Saturation Voltage – $V_{CE(sat)}$ = 0.5 Vdc (Max) @ I_C = 5.0 Adc

7 AMPERE
POWER TRANSISTORS
PNP GERMANIUM

40–60–80 VOLTS
85 WATTS

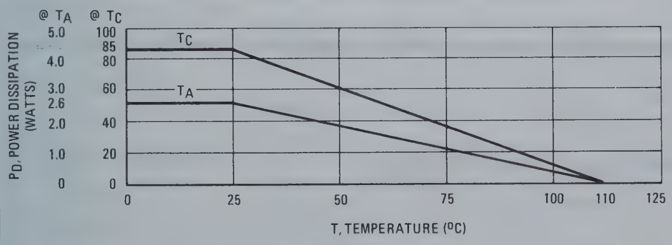


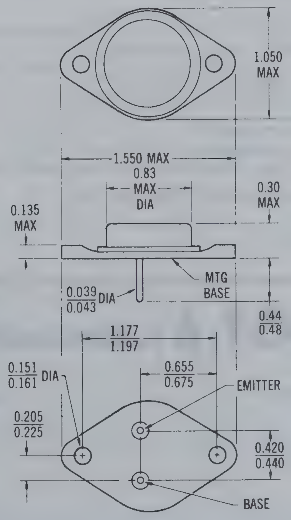
*MAXIMUM RATINGS

Rating	Symbol	2N456A	2N457A	2N458A	Unit
Collector-Emitter Voltage	V_{CEO}	20	30	40	Volts
Collector-Base Voltage	V_{CB}	40	60	80	Volts
Emitter-Base Voltage	V_{EB}	←	20	→	Volts
Collector Current	I_C	←	7.0	→	Adc
Base Current	I_B	←	3.0	→	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	←	85 1.0	→	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +110	→	°C

*Indicates JEDEC Registered Data.

FIGURE 1 – POWER-TEMPERATURE DERATING CURVE




1.050 MAX
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
0.039 / 0.043 DIA
MTG BASE
0.44 / 0.48
1.177 / 1.197
0.151 / 0.161 DIA
0.655 / 0.675
EMITTER
0.205 / 0.225
0.420 / 0.440
BASE

CASE 11
TO-3

COLLECTOR CONNECTED TO CASE

***ELECTRICAL CHARACTERISTICS** (T_C = 25°C unless otherwise noted)

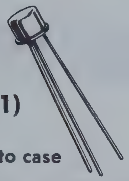
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 200 mAdc, I_B = 0)	2N456A		20	–	
	2N457A		30	–	
	2N458A		40	–	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 20 Vdc, I_E = 0)	2N456A		–	0.5	
(V_{CB} = 30 Vdc, I_E = 0)	2N457A		–	0.5	
(V_{CB} = 40 Vdc, I_E = 0)	2N458A		–	0.5	
(V_{CB} = 40 Vdc, I_E = 0)	2N456A		–	2.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N457A		–	2.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N458A		–	2.0	
(V_{CB} = 40 Vdc, I_E = 0, T_C = +71°C)	2N456A		–	10	
(V_{CB} = 60 Vdc, I_E = 0, T_C = +71°C)	2N457A		–	10	
(V_{CB} = 80 Vdc, I_E = 0, T_C = +71°C)	2N458A		–	10	
Emitter-Base Cutoff Current (V_{EB} = 20 Vdc, I_C = 0)		I_{EBO}	–	2.0	mAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 1.0 Adc, V_{CE} = 1.5 Vdc)			40	–	
(I_C = 3.0 Adc, V_{CE} = 1.5 Vdc)			35	–	
(I_C = 5.0 Adc, V_{CE} = 1.5 Vdc)			30	90	
(I_C = 7.0 Adc, V_{CE} = 1.5 Vdc)			22	–	
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 500 mAdc)		$V_{CE(sat)}$	–	0.5	Vdc
Base-Emitter Voltage (I_C = 5.0 Adc, V_{CE} = 1.5 Vdc)		V_{BE}	–	1.5	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)		f_T	200	–	kHz
Input Impedance (I_C = 5.0 Adc, V_{CE} = 1.5 Vdc)		h_{ie}	–	28	Ohms

*Indicates JEDEC Registered Data.

2N459,A (GERMANIUM)

For Specifications, See 2N378 Data.

2N460, 2N461 (GERMANIUM)



CASE 31(1)
(TO-5)
Base connected to case

PNP germanium transistor for general purpose industrial applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Volts
Collector-Emitter Voltage (R_{BE} = 1 K)	V_{CER}	35	Volts
Emitter-Base Voltage	V_{EB}	10	Volts
Collector Current	I_C	400	mA
Collector Dissipation at 25° C Case Temperature Derate above 25° C at 25° C Ambient Temperature Derate above 25° C	P_D	 500 6.7 225 3.0	 mW mW/° C mW mW/° C
Junction Temperature Range	T_J	-65 to +100	° C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristics		Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 45 Vdc)		I_{CBO}	---	---	15	μAdc
Emitter-Base Cutoff Current (V_{EB} = -10 Vdc)		I_{EBO}	---	---	10	μAdc
Collector-Emitter Voltage (I_C = 1 mAdc, R_{BE} = 1 K)		BV_{CER}	35	---	---	Vdc
Small-Signal Current Gain (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N460 2N461	h_{fb}	0.94 0.955	0.96 0.968	0.972 0.988	---
Small-Signal Current Gain (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N460 2N461	h_{fe}	17 31	---	36 200	---
Reverse Voltage Ratio (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N460 2N461	h_{rb}	--- ---	2.0 3.0	15 15	$X10^{-4}$
Input Resistance (V_{CB} - -6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N460 2N461	h_{ib}	25 25	30 ---	40 40	Ohms
Output Admittance (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N460 2N461	h_{ob}	--- ---	0.8 0.5	1.5 1.5	μmho
Frequency Cutoff (V_{CE} = -5 Vdc, I_E = 1 mAdc)	2N460 2N461	$f_{\alpha b}$	--- ---	1.2 4.0	--- ---	MHz
Output Capacitance (V_{CB} = -10 Vdc, I_E = 1 mAdc, f = 1 MHz)		C_{ob}	---	20	---	pF
Noise Figure (V_{CE} = -4.5 Vdc, I_E = 0.5 mAdc, R_g = 1 K, f = 1 kHz)	2N460 2N461	NF	--- ---	5.0 4.0	--- ---	dB

2N464 thru 2N467 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for general purpose applications in the audio-frequency range.

MAXIMUM RATINGS

Rating	Symbol	2N464	2N465	2N466	2N467	Unit
Collector-Base Voltage	V_{CB}	45	45	35	35	Volts
Collector-Emitter Voltage	V_{CER}	40	30	20	15	Volts
Emitter-Base Voltage	V_{EB}	12				Volts
DC Collector Current	I_C	500				mA
Max. Junction & Storage Temperature	T_J and T_{stg}	100				°C
Collector Dissipation, Ambient Derate above 25°C	P_D	200 2.67				mW mW/°C
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375				°C/mW

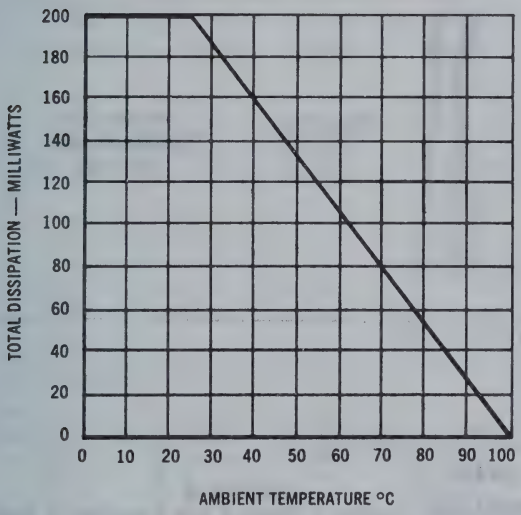
ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

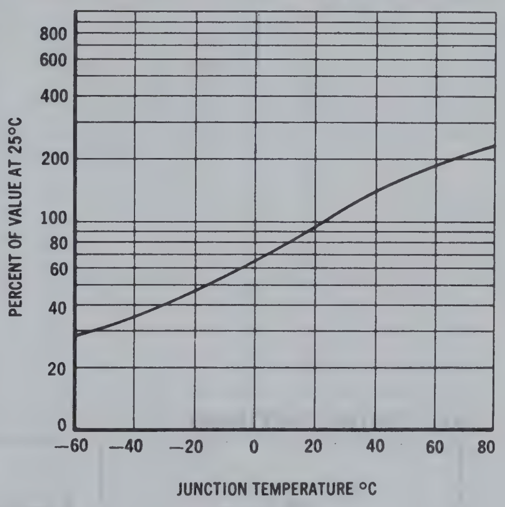
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 0.6 mAdc, R_{BE} = 10 K ohms)	2N464	BV_{CER}	40	–	–	Vdc
	2N465		30	–	–	
	2N466		20	–	–	
	2N467		15	–	–	
Collector-Base Cutoff Current (V_{CB} = 20 Vdc)		I_{CBO}	–	6.0	15	μAdc
Small Signal Current Gain Cutoff Frequency (V_{CB} = 6 Vdc, I_E = 1 mAdc)	2N464	$f_{\alpha b}$	–	0.7	–	MHz
	2N465		–	0.8	–	
	2N466		–	1.0	–	
	2N467		–	1.2	–	
Small Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	2N464	h_{fe}	14	26	–	–
	2N465		27	45	–	
	2N466		56	90	–	
	2N467		112	180	–	

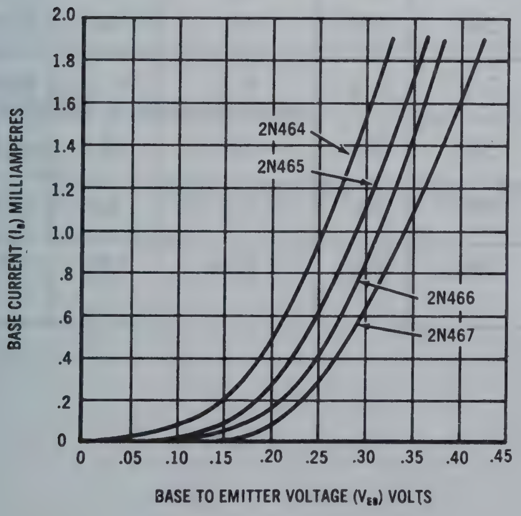
2N464 thru 2N467 (continued)

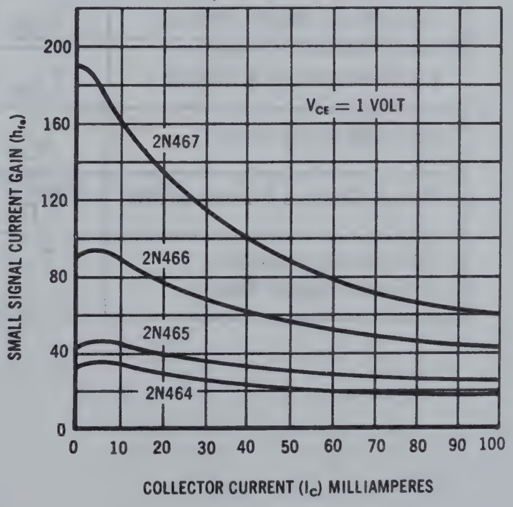
ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
Small Signal Input Impedance (V_{CE} = 6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	2N464	h_{ie}	–	900	–	Ohms
	2N465		–	1400	–	
	2N466		–	3000	–	
	2N467		–	5500	–	
Small Signal Power Gain (V_{CE} = 6 Vdc, I_E = 1.0 mAdc, f = 1 kHz, matched)	2N464	G_e	–	40	–	dB
	2N465		–	42	–	
	2N466		–	44	–	
	2N467		–	45	–	
Noise Figure (V_{CE} = 2.5 Vdc, I_E = 0.5 mAdc, f = 1 kHz, R_S = 10 Kohms, Δf = 1 Hz		NF	–	–	22	dB


POWER-TEMPERATURE DERATING CURVE


SMALL SIGNAL CURRENT GAIN versus TEMPERATURE


Input Current versus Emitter-Drive Voltage


Small Signal Current Gain versus Collector Current

(common emitter 1 kHz)

2N499

(2N499 JAN AVAILABLE)

2N499A

(2N499A JAN AVAILABLE)

2N502

2N502A

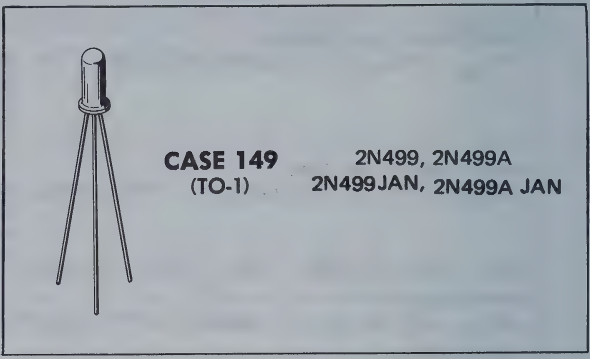
(2N502A JAN AVAILABLE)

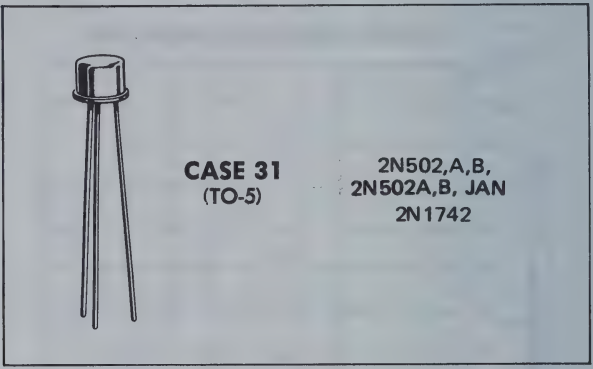
2N502B

(2N502B JAN AVAILABLE)

2N1742

Germanium PNP high frequency transistors designed for driver applications, small-signal amplification, wide band video amplifiers, and VHF/UHF oscillators.


CASE 149
(TO-1)
2N499, 2N499A
2N499JAN, 2N499A JAN


CASE 31
(TO-5)
2N502,A,B,
2N502A,B, JAN
2N1742

MAXIMUM RATINGS

Rating	Symbol	2N499 2N499 JAN 2N499A 2N499A JAN	2N502	2N502A, B 2N502A JAN 2N502B JAN	2N1742	Unit
Collector-Base Voltage	V_{CB}	30	20	30	20	Vdc
Emitter-Base Voltage	V_{EB}	0.5	0.5	0.5	0.5	Vdc
Collector Current	I_C	50	50	50	50	mAdc
Total Device Dissipation	P_D	60	60	75	60	mW
Operating Junction Temperature Range	T_J	100	100	100	125	°C

2N499, A/2N499JAN, A/2N502, A, B/2N502 JAN, A, B/2N1742 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector Cutoff Current		I_{CBO}			µAdc
(V_{CB} = 10 Vdc, I_E = 0)	2N502, A, B		-	5.0	
	2N502A, B JAN		-	4.0	
	2N1742		-	10	
(V_{CB} = 15 Vdc, I_E = 0)	2N499, A, 2N499, A JAN		-	10	
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product		f_T			MHz
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N499, A, 2N499, A JAN		120	-	
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	JAN2N502A, B		150	600	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 4.0 MHz)	2N499, A, 2N499, A JAN		-	2.5	
	2N502		-	2.0	
	2N502A, B		-	1.6	
	2N502A, B JAN		-	1.6	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 9.0 Vdc, f = 1.0 kHz)	2N499, A, 2N499, A JAN		20	80	
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N502		9.0	-	
	2N502A		15	-	
	2N502B		20	80	
	2N502A JAN		15	200	
	2N502B JAN		25	80	
Collector-Base Time Constant		$r_b'C_c$			ps
(I_E = 2.0 mAdc, V_{CB} = 10 Vdc, f = 46 MHz)	2N499, A JAN		5.0	50	
	2N499		-	250	
	2N499A		5.0	250	
	2N502		-	120	
	2N502A, B		5.0	50	
	2N502A, B JAN		5.0	25	
Noise Figure		NF			dB
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 200 MHz)	2N502A, 2N502A JAN		-	7.0	
	2N502B, 2N502B JAN		-	7.0	
(V_{CC} = 12 Vdc, I_E = 2.5 mAdc, f = 200 MHz)	2N1742		-	5.5	
FUNCTIONAL TESTS					
Power Gain		P_G			dB
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 100 MHz)	2N499, A, 2N499, A JAN		7.5	-	
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 200 MHz)	2N502		8.0	-	
	2N502A		10	-	
	2N502B		10	-	
	2N502A, B JAN		10	20	
(V_{CB} = 12 Vdc, I_E = 2.5 mAdc, f = 200 MHz)	2N1742		14	19	

2N508 (GERMANIUM)

FOR SPECIFICATIONS, SEE 2N322 DATA.

2N508A (GERMANIUM)

CASE 31 (1)
(TO-5)
Base connected to case

PNP Germanium Milliwatt transistor designed for low noise audio and switching applications.

- Small-Signal Current Gain – h_{fe} = 180 (Max) @ I_E = 1.0 mAdc
- Low Noise Figure Applications – NF = 5.0 dB (Max) @ I_C = 1.0 mAdc

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
*Collector-Emitter Voltage (R_{BE} = 10 kohms)	V_{CER}	25	Vdc
*Collector-Emitter Voltage	V_{CES}	30	Vdc
*Collector-Base Voltage	V_{CB}	30	Vdc
*Emitter-Base Voltage	V_{EB}	10	Vdc
*Collector Current	I_C	200	mAdc
*Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 2.67	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

*Indicates JEDEC Registered Data

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
*Collector-Emitter Breakdown Voltage (I_C = 600 μAdc, R_{BE} = 10 k ohms)	BV_{CER}	25	-	Vdc
*Collector Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	-	7.0	μAdc
*Emitter Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	I_{EBO}	-	7.0	μAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 20 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	100	200	-
*Base-Emitter Voltage (I_C = 20 mAdc, V_{CE} = 1.0 Vdc)	V_{BE}	0.18	0.32	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Cutoff Frequency (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	$f_{\alpha b}$	2.5	-	MHz
*Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 1.0 mAdc, f = 1.0 MHz)	C_{ob}	-	35	pF
*Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	26	31	Ohms
*Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	1.0	17	x 10^{-4}
*Small-Signal Current Gain (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	75	180	-
*Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	0.1	0.9	μmhos
Noise Figure (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, R_S = 500 ohms, f = 1.0 kHz, Δf = 1.0 Hz)	NF	-	5.0	dB

*Indicates JEDEC Registered Data.

2N524 thru 2N527 (GERMANIUM)

CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistor for switching and amplifier applications in the audio-frequency range. Available for military and high-reliability industrial purposes.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current	I_C	500	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation @ 25°C Ambient	P_D	225	mW
Thermal Resistance Junction to Ambient	θ_{JA}	0.333	°C/mW
Thermal Resistance (infinite heat sink)	θ_{JC}	0.15	°C/mW

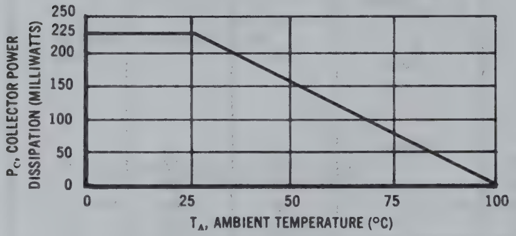
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristics		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)		I_{CBO}	-	10	μAdc
Emitter Cutoff Current (V_{EB} = 15 Vdc, I_C = 0)		I_{EBO}	-	10	μAdc
Collector-Emitter Breakdown Voltage (I_C = 0.6 mAdc, R_{BE} = 10K)		BV_{CER}	30	-	Vdc
Collector-Emitter Reach Through (Punch-Thru) Voltage (V_{EB} = 1 Vdc, VTVM Z ≥ 1 Megohm)		V_{RT}	30	-	Vdc
Static Forward-Current Transfer Ratio (V_{CE} = 1 Vdc, I_C = 20 mAdc)	2N524	h_{FE}	25	42	-
	2N525		34	65	-
	2N526		53	90	-
	2N527		72	121	-
Small-Signal Short-Circuit Forward Current Transfer Ratio Frequency Cutoff (V_{CB} = 5 Vdc, I_E = 1 mAdc)	2N524	$f_{\alpha b}$	0.8	5.0	MHz
	2N525		1.0	5.5	
	2N526		1.3	6.5	
	2N527		1.5	7.0	
Output Capacitance (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 MHz)		C_{ob}	5.0	40	pF
Small-Signal Open Circuit Output Admittance (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524	h_{ob}	0.10	1.3	μmho
	2N525		0.10	1.2	
	2N526		0.10	1.0	
	2N527		0.10	0.9	
Small-Signal Open Circuit Reverse Transfer Voltage Ratio (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524	h_{rb}	1.0	10	$X10^{-4}$
	2N525		1.0	11	
	2N526		1.0	12	
	2N527		1.0	14	
Small-Signal Short Circuit Input Impedance (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524	h_{ib}	26	36	ohms
	2N525		26	35	
	2N526		26	33	
	2N527		26	31	
Collector-Emitter Saturation Voltage		$V_{CE\ (sat)}$			
(I_B = 2 mAdc, I_C = 20 mAdc)	2N524				
(I_B = 1.33 mAdc, I_C = 20 mAdc)	2N525		-	130	mVdc
(I_B = 1.0 mAdc, I_C = 20 mAdc)	2N526		-	130	
(I_B = 0.67 mAdc, I_C = 20 mAdc)	2N527		-	130	
			-	130	
Base Input Voltage (V_{CE} = 1 Vdc, I_C = 20 mAdc)	2N524	V_{BE}	220	320	mVdc
	2N525		200	300	
	2N526		190	280	
	2N527		180	260	

ELECTRICAL CHARACTERISTICS (continued)

Characteristics		Symbol	Min	Max	Unit
Noise Figure (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz, BW = 1 Hz		NF	-	15	dB
Small-Signal Short-Circuit Forward-Current Transfer Ratio (V_{CE} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{fe}			-
	2N524		18	41	
	2N525		30	64	
	2N526		44	88	
	2N527		60	120	

POWER-TEMPERATURE DERATING CURVE

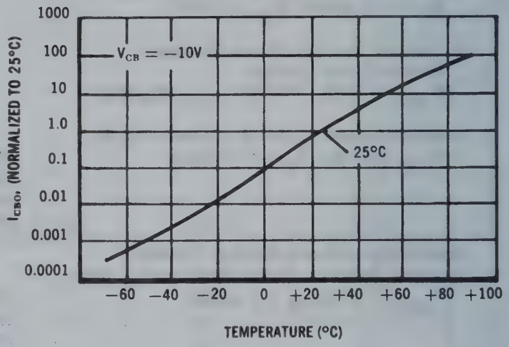


The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

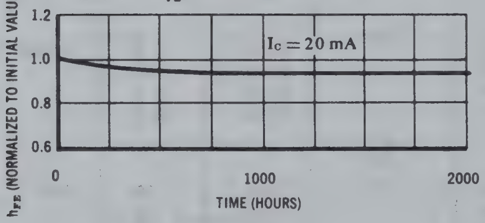
This curve has a value of 225mW at case temperatures of 25°C and is 0 mW at 100°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{100° - T_A}{0.333}$$

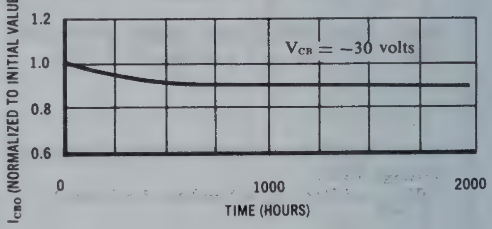
COLLECTOR CUTOFF CURRENT versus TEMPERATURE



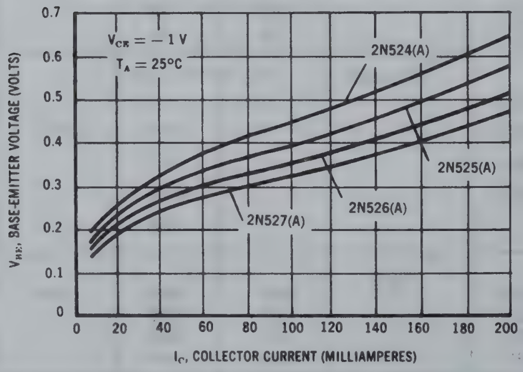
h_{FE} VARIATION WITH TIME



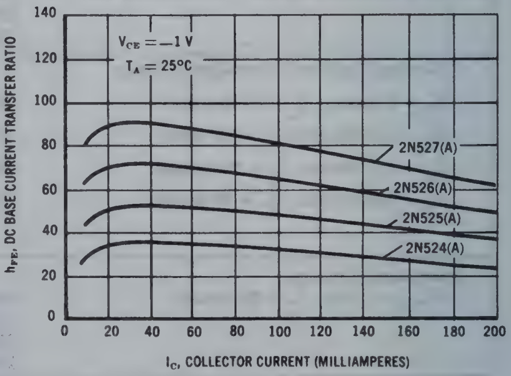
I_{CBO} VARIATION WITH TIME



COMMON EMITTER INPUT VOLTAGE versus COLLECTOR CURRENT



D-C BASE CURRENT GAIN versus COLLECTOR CURRENT



2N554 (GERMANIUM)
2N555

For Specifications, See 2N178 Data.

JAN 2N559-1 (GERMANIUM)
JAN 2N559-2
JAN 2N559-3*

CASE 22
(TO-18)

Collector connected to case

PNP germanium mesa transistors designed for military and industrial high-reliability, high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	50	mAdc
Base Current	I_B	50	mAdc
Emitter Current	I_E	50	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0	mW mW/^oC
Operating Junction Temperature Range	T_J	-65 to +100	^oC
Storage Temperature Range	T_{stg}	-65 to +150	^oC

* Level 3 reliability data shown for information only. Qualification tests will be initiated upon established customer requirements.

RELIABILITY RATINGS†

Reliability Level Indicator	QUALITY LEVELS (LTPD)				RELIABILITY LEVELS Maximum failure rate (λ) during first 1000 hours with 90% confidence.						Est. Max Failure Rate in Conservatively Designed Equipment %/1000 Hrs
					Operation Life		Storage Life				
	Group A Subgroups		Group B Subgroups		$P_D = 150$ mW $I_E = 50$ mA $T_A = 25$°C		$T_A = 100$°C		$T_A = 150$°C		
	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	
(1)	3.0	5.0	10	20	10	20	10	20	20	—	0.1
(2)	1.5	3.0	5.0	15	5.0	15	1.5	3.0	7.0	20	0.01
(3)*	1.0	2.0	3.0	7.0	2.0	5.0	0.2	0.5	1.0	3.0	0.001

† This table relates the statistical sampling requirements in the specification to the reliability levels for the transistor.

* Level 3 reliability data shown for information only. Qualification tests will be initiated upon established customer requirements.

TABLE I – GROUP A INSPECTION

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1													
Visual and Mechanical Examination	2071	10	7	5	7	5	3	—	—	—	—	—	—
SUBGROUP 2		5	3	2	3	1.5	1.0						
Emitter-Base Cutoff Current (V_{EB} = -1 Vdc)	3061 Condition D							I_{EBO}	—	5.0	>5 to 10	>10	µAdc
Collector-Base Cutoff Current (V_{CB} = -5 Vdc)	3036 Condition D							I_{CBO}	—	3.0	>3 to 5	> 5	µAdc
Emitter-Base Breakdown Voltage (I_E = -200 µAdc)	3026 Condition D							BV_{EBO}	5.0	—	3.5 to <5	< 3.5	Vdc
Collector-Emitter Breakdown Voltage (I_C = -100 µAdc)	3011 Condition C							BV_{CES}	15	—	12 to <15	<12	Vdc
SUBGROUP 3		5	3	2	3	1.5	1.0						
Collector-Emitter Saturation Voltage (I_C = -50 mAdc, I_B = -1.5 mAdc)	3071							$V_{CE(sat)}$	—	1.0	>1.0 to 1.2	> 1.2	Vdc
(I_C = -10 mAdc, I_B = -0.4 mAdc)									—	0.3	>0.3 to 0.35	> 0.35	
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.4 mAdc)	3066 Condition A							$V_{BE(sat)}$	0.32	0.44	0.30 to <0.32 and 0.44 to 0.50	< 0.30 and > 0.50	Vdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc)	3076							h_{FE}	25	150	20 to <25 and >150 to 200	< 20 and >200	—
SUBGROUP 4		5	3	2	3	1.5	1.0						
Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, $C_{CB} = 2^{+0.5}_{-0}$ pF)	3251 Condition A							t_r	—	95	> 95 to 115	>115	ns
Storage Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms)	3251 Condition A							t_s	—	95	> 95 to 115	> 115	ns
Fall Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms, $C_{CB} = 2^{+0.5}_{-0}$ pF)	3251 Condition A							t_f	—	100	> 100 to 120	>120	ns

NOTES:

① Total is defined as the sum of the major and minor defectives.

TABLE II – GROUP B INSPECTION

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1													
Physical Dimensions	2066	20	15	7	—	—	—	—	—	—	—	—	—
SUBGROUP 2		5	3	2	3	1.5	1						
Moisture Resistance (No initial conditioning; one cycle; only steps 1 to 6)	1021							—	—	—	—	—	—
End-Point Tests:													
Emitter-Base Cutoff Current (V_{EB} = -1 Vdc)	3061 Condition D							I_{EBO}	—	10	>10 to 20	>20	μAdc
Collector-Base Cutoff Current (V_{CB} = -5 Vdc)	3036 Condition D							I_{CBO}	—	5.0	>5 to 10	>10	μAdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc)	3076							h_{FE}	20	200	15 to <20 and >200 to 250	<15 and >250	—
SUBGROUP 3		20	15	7	10	5	3						
Tension	2036 Condition A							—	—	—	—	—	—
Solderability	2026							—	—	—	—	—	—
Temperature Cycling (5 cycles) $T_{(high)} = 100^{+5}_{-0}$ °C 2N559 (1) $T_{(high)} = 150 \pm 5$ °C 2N559 (2), 2N559 (3)	1051 Condition B							—	—	—	—	—	—
Thermal Shock (Glass Strain)	1056 Condition A							—	—	—	—	—	—
Moisture Resistance	1021							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 4		20	15	7	10	5	3						
Shock (Non-operating; 5 blows: 1500 G in Orientations X_1, Y_1, Y_2, and Z_1 (total = 20 blows)	2016							—	—	—	—	—	—
Constant Acceleration (20,000 G, Orientations X_1, Y_1, Y_2, and Z_1)	2006							—	—	—	—	—	—
Vibration Fatigue (No bias applied)	2046							—	—	—	—	—	—
Vibration, Variable Frequency (1 cycle each in Orientations X_1, Y_1, and Z_1)	2056							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 5		20	15	7	10	5	3						
Terminal Strength - Lead Fatigue ②	2036 Condition E							—	—	—	—	—	—
SUBGROUP 6		20	—	—	10	—	—						
High-Temperature Life (Non-operating) ($T_{stg} = 100^{+0}_{-5}$ °C 2N559 (1) ONLY	1031							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 7		—	20	3	—	7	1						
High-Temperature Life (Non-operating) ($T_{stg} = 150^{+0}_{-5}$ °C) 2N559 (2), 2N559 (3)	1031							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 8		20	15	5	10	5	2						
Steady-State Operation Life ($I_E = 50^{+0}_{-5}$ mAdc, $P_D = 150^{+0}_{-15}$ mW, $T_A = 25 \pm 3$°C)	1026							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													

NOTES: ① Total is defined as the sum of the major and minor defectives.

② Rejects from prior electrical-test samples from the same lot may be used for this test.

TABLE III – GROUP C INSPECTION*

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1		10	7	5	5	3	2						
Output Capacitance (V_{CB} = -5 Vdc, I_E = 0, f = 100 kHz)	3236							C_{ob}	—	6.0	>6 to 10	>10	pF
Current-Gain — Bandwidth Product (I_E = 10 mAdc, V_C = -1 Vdc, f = 100 MHz)	3261							f_T	300	1000	250 to <300 and >1000	<250	MHz
Delay Plus Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ ± 0.5 Vdc, I_{B1} = -1 mAdc, R_C = 300 ohms, C_{CB} = $2^{+0.5}_{-0}$ pF, C_{BE} = 2 ± 0.5 pF	3251 Condition A							$t_d + t_r$	—	50	>50 to 75	>75	ns
SUBGROUP 2		10	7	5	5	3	2						
Collector-Emitter Cutoff Current (V_{CE} = 5 Vdc, T_A = + 55°C)	3041 Condition C							I_{CES}	—	40	>40 to 50	>50	μAdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc, T_A = -55°C)	3076							h_{FE}	10	—	8 to <10	<8	—
SUBGROUP 3		20	15	7	10	5	3						
Salt Atmosphere (Corrosion)	1041							—	—	—	—	—	—
End-Point Tests: Same as Group B, Subgroup 2													
SUBGROUP 4		—	20	10	—	10	5						
High-Temperature Life (Non-operating) (T_{stg} = 100^{+0}_{-5} °C)	1031							—	—	—	—	—	—
End-Point Tests:													
Emitter-Base Breakdown Voltage (I_E = -300 μAdc)	3026 Condition D							BV_{EBO}	5.0	—	3.5 to <5	<3.5	Vdc
Collector-Emitter Breakdown Voltage (I_C = -100 μAdc)	3011 Condition C							BV_{CES}	12	—	8 to <12	<8	Vdc
Collector-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.5 mAdc)	3071							$V_{CE(sat)}$	—	0.3	>0.3 to 0.6	>0.6	Vdc
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.4 mAdc)	3066 Condition A							$V_{BE(sat)}$	0.31	0.47	0.25 to <0.31 and >0.47 to 0.55	<0.25 and >0.55	Vdc
Delay Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, C_{CB} = $2^{+0.5}_{-0}$ pF, C_{BE} = 2 ± 0.5 pF)	3251 Condition A							t_d	10	35	<10 and >35 to 45	>45	ns
Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, C_{CB} = $2^{+0.5}_{-0}$ pF)	3251 Condition A							t_r	15	105	<15 and >105 to 125	>125	ns
Storage Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms)	3251 Condition A							t_s	15	105	<15 and >105 to 125	>125	ns

* Group C is to be performed on the first lot and every 6 months thereafter.

NOTE: ① Total is defined as the sum of the major and minor defectives.

2N618 (GERMANIUM)

For Specifications, See 2N375 Data.

2N650A, 2N650 (GERMANIUM)
2N651A, 2N651
2N652A, 2N652

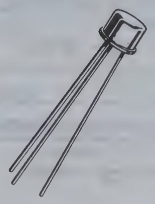
GERMANIUM PNP MILLIWATT TRANSISTORS

. . . designed primarily for low-power audio amplifier and medium-speed switching applications.

- Stabilization Bake at 100°C for 120 Hours for Greater Gain Stability
- Low Collector-Emitter Saturation Voltage — 0.2 Vdc Typ @ I_C = 200 mA

AUDIO TRANSISTORS
GERMANIUM PNP

45 VOLTS
200 MILLIWATTS



*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (R_{BE} = 10 k ohms)	V_{CER}	30	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current — Continuous (1)	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 2.67	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

Maximum lead temperature is 250°C for 3.0 seconds, 1/16″ ± 1/32″ from case.

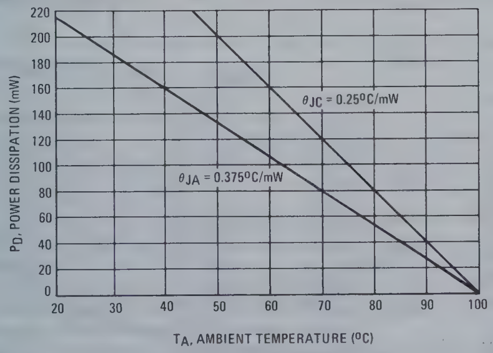
(1) Limited by power dissipation.

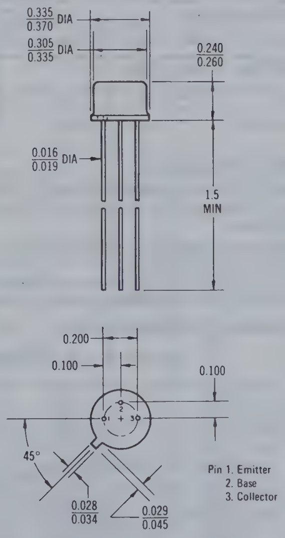
*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.250	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375	°C/mW

*Indicates JEDEC Registered Data.

FIGURE 1 — POWER-TEMPERATURE DERATING




0.335 / 0.370 DIA
0.305 / 0.335 DIA
0.240 / 0.260
0.016 / 0.019 DIA
1.5 MIN
0.200
0.100
0.100
45°
0.028 / 0.034
0.029 / 0.045
Pin 1. Emitter
2. Base
3. Collector

CASE 31 (1)
TO-5

(All leads isolated from Case)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Floating Potential (1) (V_{CB} = 45 Vdc, I_E = 0, voltmeter input resistance ≥ 10 megohms)		V_{EBF}	–	1.0	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, R_{BE} = 10 k ohms)		I_{CER}	–	600	μAdc
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)			–	10	
(V_{CB} = 45 Vdc, I_E = 0)			–	50	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +71°C)			–	100	
Emitter Cutoff Current (V_{EB} = 30 Vdc, I_C = 0)		I_{EBO}	–	10	μAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N650		30	–	
	2N650A		33	–	
	2N651, A		45	–	
	2N652, A		80	–	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)	2N650, A		–	0.250	
(I_C = 50 mAdc, I_B = 1.67 mAdc)	2N651, A		–	0.250	
(I_C = 50 mAdc, I_B = 1.25 mAdc)	2N652, A		–	0.250	
(I_C = 100 mAdc, I_B = 5.0 mAdc)	2N650, A		–	0.500	
(I_C = 100 mAdc, I_B = 3.33 mAdc)	2N651, A		–	0.500	
(I_C = 100 mAdc, I_B = 2.5 mAdc)	2N652, A		–	0.500	
Base-Emitter Voltage		V_{BE}			Vdc
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N650, A		–	0.270	
	2N651, A		–	0.260	
	2N652, A		–	0.250	
SMALL-SIGNAL CHARACTERISTICS					
Common-Base Cutoff Frequency		$f_{\alpha b}$			MHz
(I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc)	2N650, A		0.75	–	
	2N651, A		1.0	–	
	2N652, A		1.25	–	
Output Capacitance (1) (V_{CB} = 6.0 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	–	25	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc, f = 1.0 kHz)		h_{ib}	27	37	Ohms
Small-Signal Current Gain		h_{fe}			–
(I_E = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)	2N650, A		30	70	
	2N651, A		50	120	
	2N652, A		100	225	
Output Admittance (1) (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc, f = 1.0 kHz)		h_{ob}	0.15	1.0	μmhos
Noise Figure (I_E = 0.5 mAdc, V_{CE} = 4.5 Vdc, R_S = 1.0 k ohms, f = 1.0 kHz, Δ f = 1.0 Hz)		NF	–	15	dB

(1) Applies only to 2N650A, 2N651A, and 2N652A Devices

*Indicates JEDEC Registered Data.

FIGURE 2 – DC CURRENT GAIN

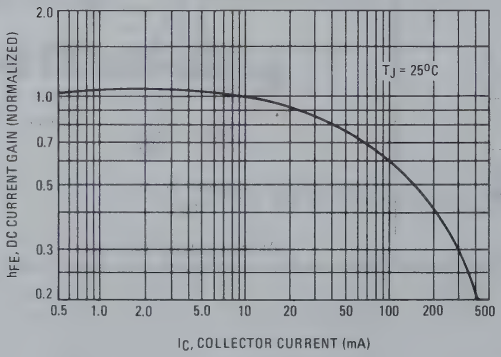
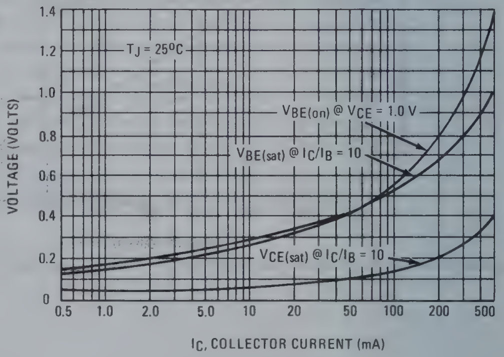


FIGURE 3 – "ON" VOLTAGES



2N653 thru 2N655 (GERMANIUM)

CASE 31(1)
(TO-5)

All leads isolated

PNP germanium transistor, for high-gain amplifier and switching service in the audio frequency range.

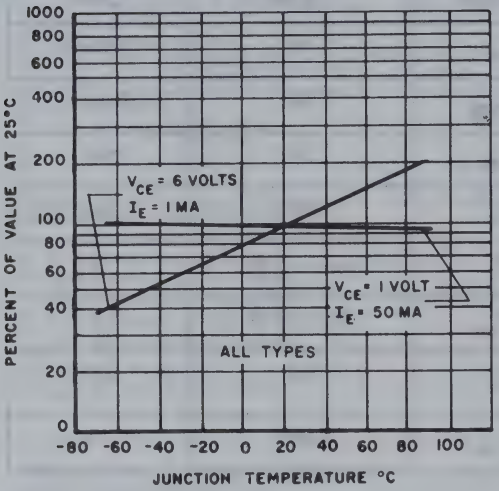
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector to Base Voltage	V_{CB}	30	Volts
Collector to Emitter Voltage	V_{CER}	25	Volts
Emitter to Base Voltage	V_{EB}	25	Volts
Collector D. C. Current *	I_C	250*	mA
Junction Temperature Limits	T_J	-65 to +100	°C
Storage Temperature Limits	T_{stg}	-65 to +100	°C
Collector Dissipation in, Ambient Derate 2.67 mW/°C above 25°C	P_D	200	mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375	°C/mW

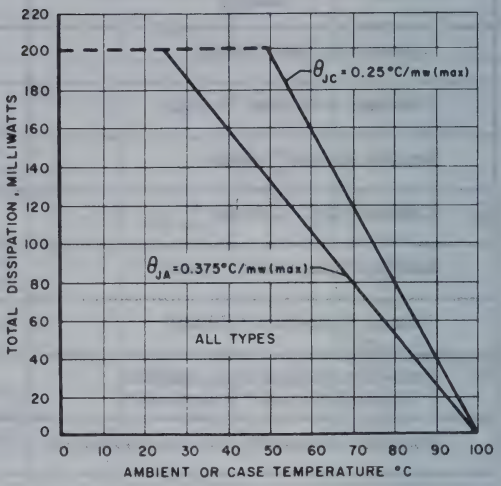
*Limited by power dissipation.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics	Symbol	2N653			2N654			2N655			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Small Signal Current Gain V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz	h_{fe}	30	49	70	50	80	125	100	130	250	-
Small Signal Input Impedance V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz	h_{ie}	750	-	2900	1500	-	4700	3000	-	8500	ohms
Small Signal Current Gain Cutoff Frequency V_{CB} = 6 V, I_E = 1.0 mA	$f_{\alpha b}$		1.5			2.0			2.5		MHz
Output Capacity V_{CB} = 6 V, I_E = 0 mA, f = 1 MHz	C_{ob}		10			10			10		pF
Noise Figure V_{CE} = 4.5 V, I_E = 0.5 mA, Rs = 1, f = kHz Δf = 1 Hz	NF		10			10			10		dB
Collector Reverse Current V_{CB} = 25 V, I_E = 0	I_{CBO}		5.0	15		5.0	15		5.0	15	μA
Emitter Reverse Current V_{EB} = 25 V, I_C = 0	I_{EBO}		5.0	15		5.0	15		5.0	15	μA
Collector-Emitter Reverse Current V_{CE} = 25 V, R_{BE} = 10 k	I_{CER}			600			600			600	μA
Base-Emitter Input Voltage V_{CE} = 6 V, I_C = 1.0 mA	V_{BE}			0.3			0.3			0.3	Vdc

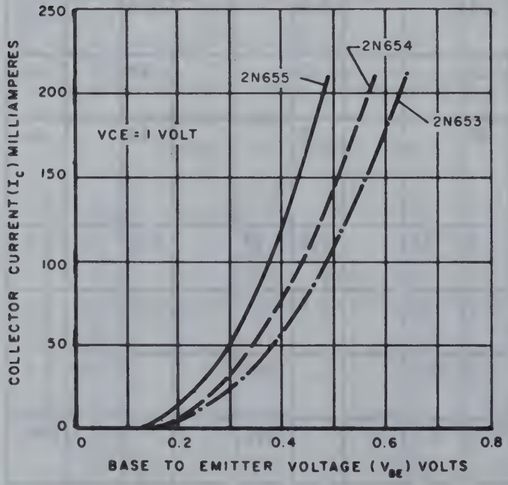


SMALL SIGNAL CURRENT GAIN (h_{fe}) versus TEMPERATURE



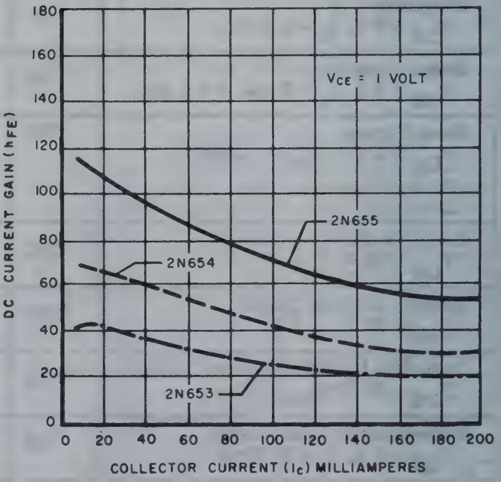
POWER-TEMPERATURE DERATING CURVE

OUTPUT CURRENT versus BASE DRIVE VOLTAGE



LARGE SIGNAL CURRENT GAIN versus COLLECTOR CURRENT

BASE TO EMITTER VOLTAGE (V_{BE}) VOLTS



2N656 (SILICON)
2N657

NPN SILICON ANNULAR TRANSISTORS

NPN silicon annular transistor designed for small-signal amplifier and general purpose switching applications.

- High Collector-Emitter Breakdown Voltage –
  BV_{CEO} = 100 Vdc (Min) @ I_C = 250 μAdc – 2N657
- High Emitter-Base Breakdown Voltage –
  BV_{EBO} = 8.0 Vdc (Min) @ I_E = 250 μAdc

**NPN SILICON
ANNULAR TRANSISTORS**

*MAXIMUM RATINGS

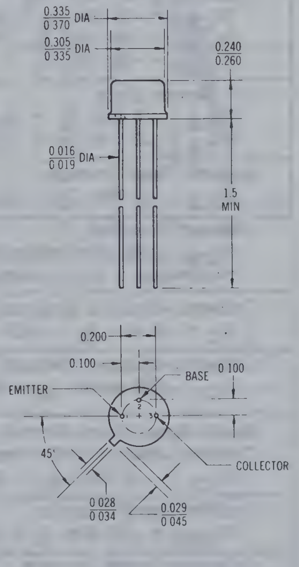
Rating	Symbol	2N656	2N657	Unit
Collector-Emitter Voltage	V_{CEO}	60	100	Vdc
Collector-Base Voltage	V_{CB}	60	100	Vdc
Emitter-Base Voltage	V_{EB}	8.0		Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.7		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	4.0 22.8		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 250 μAdc, I_B = 0) 2N656 2N657	BV_{CEO}	 60 100	 – –	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) 2N656 2N657	BV_{CBO}	 60 100	 – –	Vdc
Emitter-Base Breakdown Voltage (I_E = 250 μAdc, I_C = 0)	BV_{EBO}	8.0	–	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	–	10	μAdc
ON CHARACTERISTICS				
DC Current Gain(1) (I_C = 200 mAdc, V_{CE} = 10 Vdc)	h_{FE}	30	90	–
Collector-Emitter Saturation Voltage(1) (I_C = 200 mAdc, I_B = 40 mAdc)	$V_{CE(sat)}$	–	4.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Input Impedance(1) (I_B = 8.0 mAdc, V_{CE} = 10 Vdc)	h_{ie}	–	0.5	k ohm

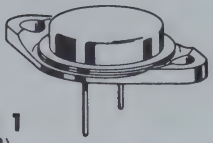
*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Length = 300 μs, Duty Cycle ≤ 2.0%.



CASE 31
(TO-5)

2N665 (GERMANIUM)



CASE 1
(TO-3)

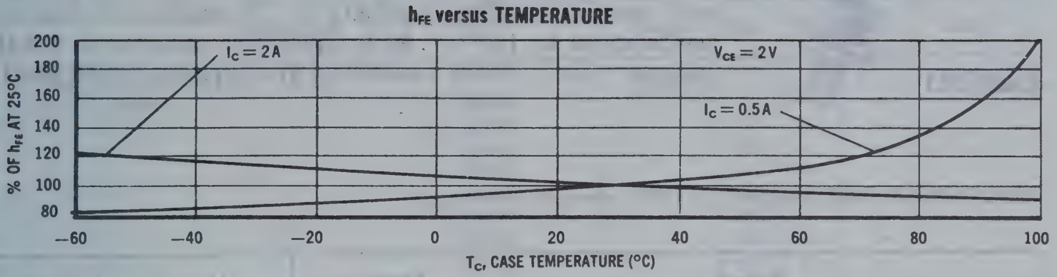
PNP germanium power transistor for driver and power output amplifier and power switching applications in military and industrial equipment.

MAXIMUM RATINGS

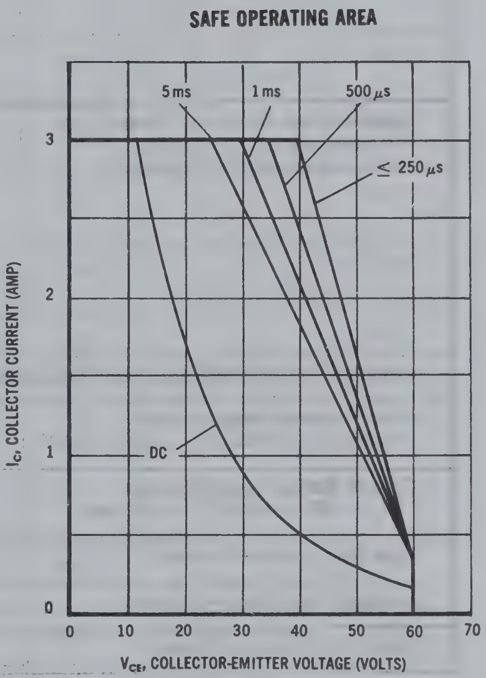
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
DC Collector Current	I_C	3.0	Amp
DC Emitter Current	I_E	5.0	Amp
Collector Junction Temperature	T_J	-65 to +95	°C
Collector Dissipation Derate above 25°C	P_D	35 0.5	Watts W/°C

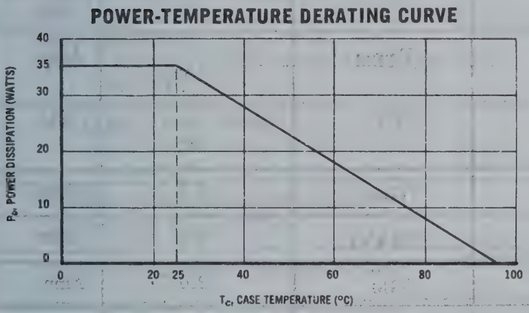
ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Emitter Cutoff Current (V_{EBO} = -40 Vdc, I_C = 0)	I_{EBO}	—	2.0	mAdc
Collector Cutoff Current (V_{CBO} = -2 Vdc, I_E = 0) (V_{CBO} = -60 Vdc, I_E = 0) (V_{CBO} = -80 Vdc, I_E = 0)	I_{CBO}	— — —	0.05 2.0 10	mAdc
DC Current Gain (V_{CE} = -2 Vdc, I_C = -0.5 Adc) (V_{CE} = -2 Vdc, I_C = -2 Adc)	h_{FE}	40 20	80 —	—
Emitter-Base Voltage (V_{CE} = -2 Vdc, I_C = -2 Adc)	V_{EB}	—	1.5	Vdc
Floating Potential (V_{CB} = -80 Vdc, voltmeter input resistance = 10 megohms min, t ≈ 1 sec)	V_{EBF}	—	1.0	Vdc
Collector-Emitter Saturation Voltage (I_C = -3 Adc, I_B = -220 mAdc)	$V_{CE(sat)}$	—	-0.9	Vdc
Collector-Emitter Voltage (I_C = -300 mAdc, I_B = 0)	V_{CEO}	40	—	Vdc
Small-Signal Short-Circuit Forward-Current Transfer-Ratio Cutoff Frequency (V_{CE} = -14 Vdc, I_C = -2 Adc)	$f_{\alpha e}$	20	—	kHz
Emitter Cutoff Current (V_{EBO} = -30 Vdc, I_C = 0, T_C = +71°C min)	I_{EBO}	—	2.0	mAdc
Collector Cutoff Current (V_{CBO} = -30 Vdc, I_E = 0, T_C = +71°C min)	I_{CBO}	—	2.0	mAdc



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

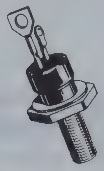




2N669 (GERMANIUM)

For Specifications, See 2N176 Data.

2N681 thru 2N689 (SILICON)



CASE 263

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 25 amperes at junction temperatures to 125°C. MCR equivalents available in TO-48 package – i.e. – 2N681 available in TO-48 package as MCR681.

MAXIMUM RATINGS (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*†	$V_{RSM(rep)}$*†		Volts
2N681		25	
2N682		50	
2N683		100	
2N684		150	
2N685		200	
2N686		250	
2N687		300	
2N688		400	
2N689		500	
Peak Reverse Blocking Voltage*	$V_{RSM(non\text{-}rep)}$*		Volts
(Transient) 2N681		35	
(non-recurrent t = 5 ms max.) 2N682		75	
2N683		150	
2N684		225	
2N685		300	
2N686		350	
2N687		400	
2N688		500	
2N689		600	
Forward Current RMS (all conduction angles)	I_T	25	Amp
Peak Forward Surge Current (One cycle, 60 Hz, T_J = -65 to +125°C)	T_{TSM}	200	Amp
Circuit Fusing Considerations (T_J = -65 to +125°C, t ≦ 8.3 ms)	I^2t	165	A^2s
Peak Gate Power-Forward	P_{GM}	5.0	Watts
Average Gate Power-Forward	$P_{G(AV)}$	0.5	Watt
Peak Gate Current-Forward	I_{GM}	2.0	Amp
Peak Gate Voltage-Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Stud Torque	—	30	in. lb.

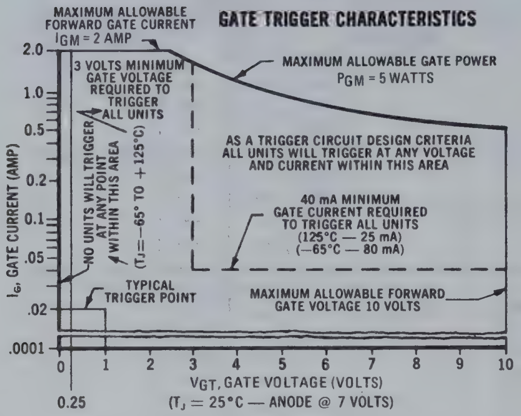
† V_{RSM} for all types can be applied on a continuous dc basis without incurring change.

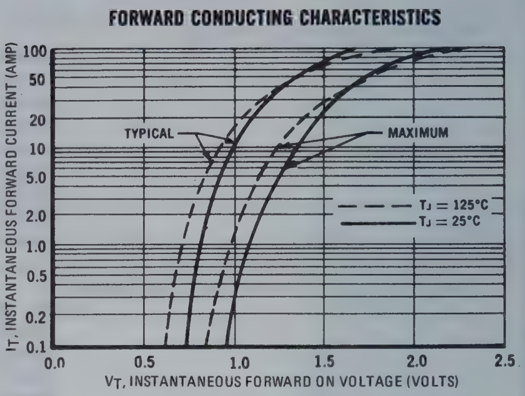
* $V_{RSM(rep)}$ ratings apply for zero or negative gate voltage.

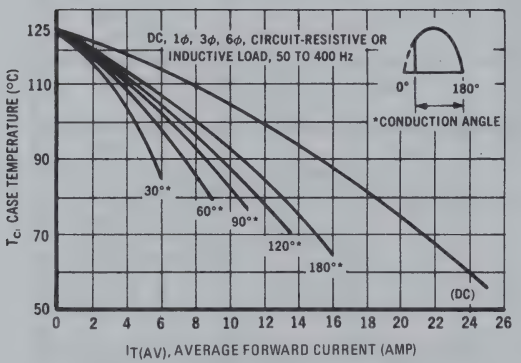
2N681 thru 2N689 (continued)

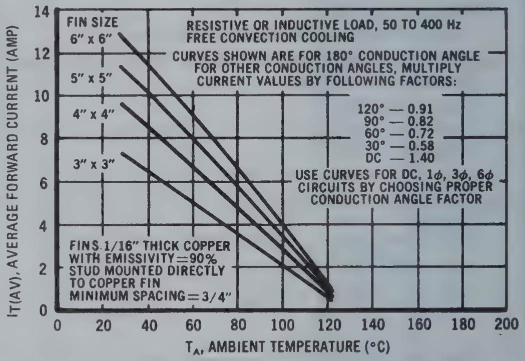
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage (T_J = 125°C)	V_{DRM}				Volts
2N681		25	—	—	
2N682		50	—	—	
2N683		100	—	—	
2N684		150	—	—	
2N685		200	—	—	
2N686		250	—	—	
2N687		300	—	—	
2N688		400	—	—	
2N689		500	—	—	
Peak Forward or Reverse Blocking Current (T_J = 125°C)	I_{DRM} I_{RRM}				mA
2N681 - 2N684		—	—	10.0	
2N685		—	—	10.0	
2N686		—	—	10.0	
2N687		—	—	10.0	
2N688		—	—	8.0	
2N689		—	—	6.0	
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)	I_{GT}	—	10	25	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)	V_{GT}	0.25	—	3.0	Volts
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_H	—	20	—	mA
Forward On Voltage (I_T = 20 Adc)	V_{TM}	—	1.1	1.5	Volts
Turn-On Time (I_T = 10A, I_G = 200 mA)	t_{gt}	—	1.0	—	μs
Turn-Off Time (I_T = 10 A; I_R = 10 A, dv/dt = 30 V/μs min, T_J = 125°C) (V_{DRM} = rated voltage)	t_q	—	30	—	μs
Forward Voltage Application Rate (Gate open, T_J = 125°C)	dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	2.0	°C/W


GATE TRIGGER CHARACTERISTICS


FORWARD CONDUCTING CHARACTERISTICS


CURRENT DERATING


SUGGESTED FIN SIZES

2N696 (SILICON)
2N697

CASE 31
(TO-5)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 13.3	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	2.0 13.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

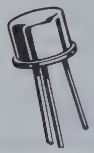
ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted.)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, R_{BE} = 10 ohms)		BV_{CER}*	40		Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	60		Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0		Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150° C)		I_{CBO}	 - -	 1.0 100	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N696 2N697	h_{FE}*	20 40	60 120	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$*	-	1.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$*	-	1.3	Vdc
DYNAMIC CHARACTERISTICS					
Current Gain-Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N696 2N697	f_T	40 50	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)		C_{ob}	-	35	pF

* Pulse Test: Pulse Length ≦ 12 ms, Duty Cycle ≦ 2.0%.

2N699 (SILICON)

NPN silicon annular transistor designed for medium-current switching and amplifier applications.



CASE 79
(TO-39)
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CER}	80	Vdc
Collector-Base Voltage	V_{CB}	120	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	0.6 4.0	Watt mW/°C
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	2.0 13.3	Watts mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

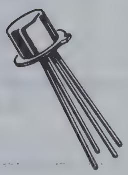
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	75	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	250	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, $R_{BE} \leqq$ 10 ohms)	BV_{CER}*	80	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	I_{CBO}	-	2.0	μAdc
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)		-	200	
Emitter Cutoff Current (V_{EB} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 150 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	40	120	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	-	5.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	20	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	ohms
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	10	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	2.5	X 10^{-4}
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	3.0	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	35	100	-
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		45	-	
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	0.1	0.5	μmhos
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	1.0	

* Pulse Test: Pulse Width ≦ 300 μs; Duty Cycle ≦ 2%.

2N700, A (GERMANIUM)



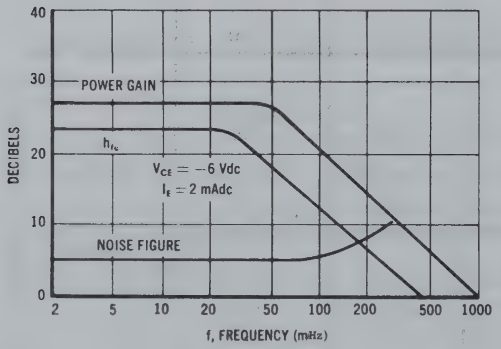
CASE 21
(TO-17)

PNP germanium mesa transistors for oscillator, frequency multiplier, wide-band mixer and wide-band amplifier applications.

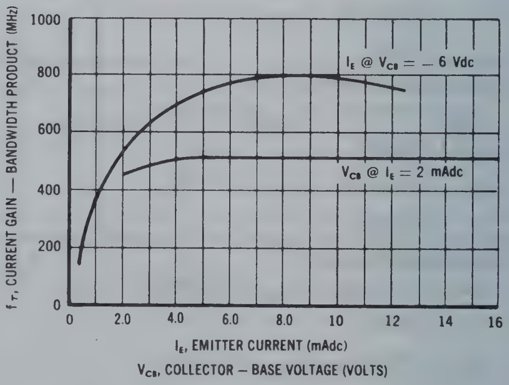
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage 2N700 2N700A	V_{CEO}	 20 25	Vdc
Emitter-Base Voltage	V_{EB}	0.2	Vdc
Collector DC Current	I_C	50	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Total Device Dissipation at 25°C Ambient Derate above 25°C	P_D	75 1.0	mW mW/°C

POWER GAIN, CURRENT GAIN, & NOISE FIGURE versus FREQUENCY



CURRENT-GAIN-BANDWIDTH PRODUCT versus CURRENT AND VOLTAGE



ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Sym	Test Conditions	Types	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	$I_C = 100\ \mu Adc,\ I_E = 0$	All Types	25	32	--	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	$I_C = 100\ \mu Adc,\ I_B = 0$	2N700 2N700A	20 25	— —	— —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	$I_E = 100\ \mu Adc,\ I_C = 0$	All Types	0.2	0.5	—	Vdc
Collector Cutoff Current	I_{CBO}	$V_{CB} = 6$ Vdc, $I_E = 0$	All Types	—	0.4	2.0	μAdc
		$V_{CB} = 6$ Vdc, $I_E = 0$, $T_A = 85^oC$	2N700 2N700A	— —	60 —	150 50	
Small Signal Forward Current Transfer Ratio	h_{fe}	$I_E = 2$ mAdc, $V_{CE} = 6$ Vdc, f = 1 kHz	All Types	4.0	10	—	—
		$I_E = 5$ mAdc, $V_{CE} = 6$ Vdc, f = 1 kHz	2N700A	—	—	50	—
		$I_E = 2$ mAdc, $V_{CE} = 6$ Vdc, f = 200 MHz	2N700 2N700A	2.5 5.0	7 —	— —	— —
Input Impedance	h_{ib}	$I_E = 2$ mAdc, $V_{CB} = 6$ Vdc, f = 1 kHz	All Types	—	17	30	Ohms
Base Resistance	r'_b	$I_E = 2$ mAdc, $V_{CB} = 6$ Vdc, f = 300 MHz	All Types	—	55	100	Ohms
Collector-Base Output Capacitance (case grounded)	C_{ob}	$V_{CB} = 6$ Vdc, $I_E = 0$, f = 100 kHz	2N700 2N700A	— —	1.1 —	1.5 1.4	pF
Power Gain	G_e	$I_E = 2$ mAdc, $V_{CB} = 6$ Vdc, f = 70 MHz (neutralized)	2N700 2N700A	20 22	23 —	— —	dB
Noise Figure	NF		All Types	—	6.0	10	dB
Power Gain	G_e	$I_E = 2$ mAdc, $V_{CB} = 6$ Vdc, f = 30 MHz (neutralized)	2N700A	26	—	—	dB

2N702 (SILICON)
2N703

NPN silicon annular transistors designed for low-level, high-speed switching applications.

CASE 22
(TO-18)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	600 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 2.0 mAdc, I_B = 0)	BV_{CEO}	25	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 5.0 μAdc, I_E = 0)	BV_{CBO}	25	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0)	I_{CEO}	-	-	10	μAdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0) (V_{CB} = 10 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	 - -	 - -	 0.5 50	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N702 2N703 (I_C = 10 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N702 2N703	h_{FE}*	 20 40 12 20	 - - - -	 60 100 - -	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	-	0.5	Vdc
Base-Emitter On Voltage* (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$*	0.7	-	0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_E = 10 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	f_T	70	150		MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	3.0	6.0	pF

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

2N705 (GERMANIUM)

CASE 22
(TO-18)

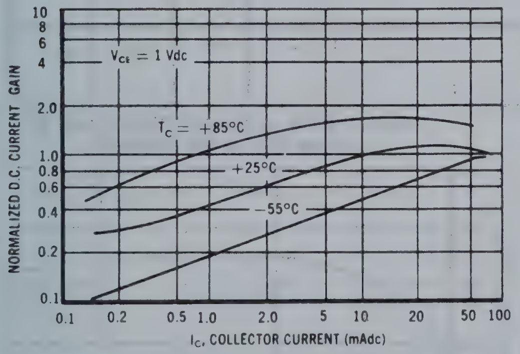
Collector connected to case

PNP germanium mesa transistor for high-speed switching applications.

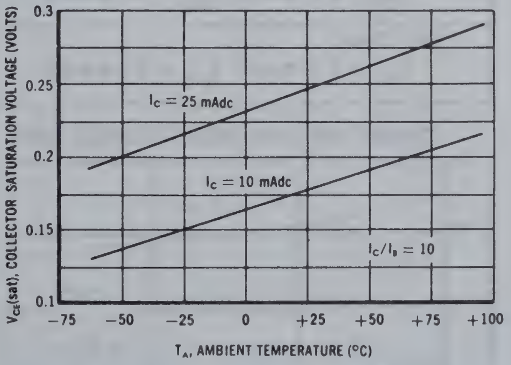
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CES}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	50	mAdc
Emitter Current	I_E	50	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65°C to +100	°C
Collector Dissipation @ T_C = 25°C Derate above 25°C	P_C	300 4.0	mW mW/°C
Collector Dissipation in Free Air	P_C	150	mW

NORMALIZED D.C. CURRENT GAIN
versus COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE
versus AMBIENT TEMPERATURE

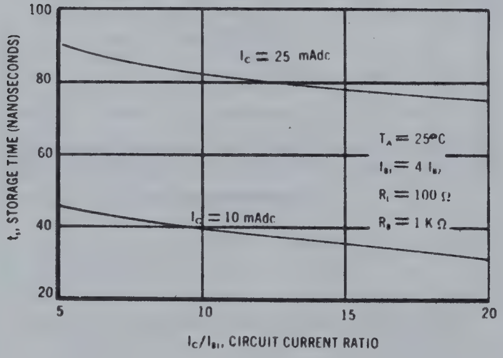


2N705 (continued)

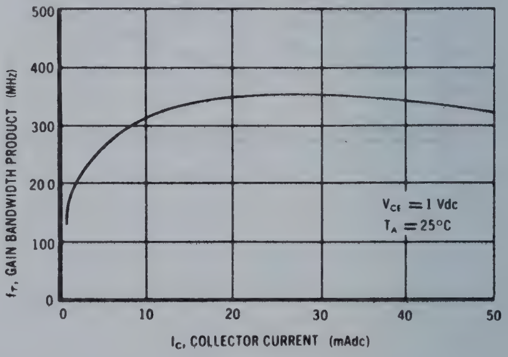
ELECTRICAL CHARACTERISTICS ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_{CE} = 100 μAdc, V_{BE} = 0)	BV_{CES}	15	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.5	–	–	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	–	0.2	3.0	μAdc
DC Forward Current Transfer Ratio (V_{CE} = .3 Vdc, I_C = 10 mAdc)	h_{FE}	25	40	–	–
Collector Saturation Voltage (I_B = .4 mAdc, I_C = 10 mAdc)	$V_{CE(sat)}$	–	0.18	0.3	Vdc
(I_B = 5 mAdc, I_C = 50 mAdc)		–	0.45	–	
Base-Emitter Voltage (I_B = .4 mAdc, I_C = 10 mAdc)	V_{BE}	0.34	0.39	0.44	Vdc
Small Signal Forward Current Transfer Ratio (V_{CE} = 1.0 Vdc, I_C = 10 mAdc, f = 100 MHz)	h_{fe}	–	9.0	–	
Collector Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	–	5.0	–	pF
Input Capacitance (V_{BE} = 2 Vdc)	C_{ib}	–	3.5	–	pF
Common Base Alpha Cutoff Frequency (V_{CB} = 5 Vdc, I_C = 10 mAdc)	$f_{\alpha b}$	–	300	–	MHz
Delay + Rise Time (I_C = 10 mAdc, I_B = 1 mAdc)	$t_d + t_r$	–	55	75	ns
Storage Time (I_{B1} = 1.0 mAdc, I_{B2} = .25 mAdc)	t_s	–	65	100	ns
Fall Time (I_{B1} = 1.0 mAdc, I_{B2} = .25 mAdc)	t_f	–	70	100	ns

STORAGE TIME versus CIRCUIT CURRENT RATIO



CURRENT GAIN — BANDWIDTH PRODUCT (f_T) versus COLLECTOR CURRENT



2N706, A, B (SILICON)

(2N706JAN AVAILABLE)
2N753

CASE 22
(TO-18)
Collector connected to case

NPN silicon annular switching transistors for high-speed switching applications.

MAXIMUM RATINGS

Rating		Symbol	Value	Unit
Collector-Base Voltage		V_{CB}	25	Volts
Collector-Emitter Voltage *		V_{CER}*	20	Volts
Emitter-Base Voltage	2N706 2N706A 2N706B 2N753	V_{EB}	3.0 5.0 5.0 5.0	Volts
Junction Temperature		T_J	175	°C
Storage Temperature		T_{stg}	-65 to +175	°C
Total Device Dissipation at 25° C Case Temperature (Derate 6.67 mW/°C above 25°C)		P_D	1.0	Watt
Total Device Dissipation at 25° C Ambient Temperature (Derate 2 mW/°C above 25°C)		P_D	0.3	Watt
Total Device Dissipation at 100°C Case Temperature (Derate 6.67 mW/°C above 100°C)		P_D	0.5	Watt

**Refers to collector breakdown voltage in the high current region when $R_{be} = 10\Omega$*

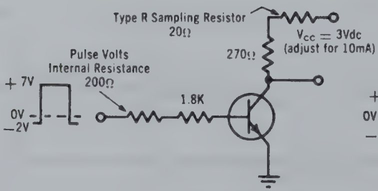
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Type	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 15Vdc, I_E = 0) (V_{CB} = 15Vdc, I_E = 0, T_A = 150 °C) (V_{CB} = 25Vdc, I_E = 0)	All Types All Types 2N706A, 2N706B, 2N753	I_{CBO}	- - -	0.005 3.0 -	0.5 30 10	μAdc
Collector-Emitter Cutoff Current (V_{CE} = 20Vdc, R_{be} = 100k)	2N706A, 2N706B, 2N753	I_{CER}	-	-	10	μAdc
Emitter Cutoff Current (V_{EB} = 3Vdc, I_c = 0) (V_{EB} = 5Vdc, I_c = 0)	2N706 2N706A, 2N706B, 2N753	I_{EBO}	- -	- -	10 10	μAdc
Collector-Emitter Breakdown Voltage * (I_C = 10mAdc, I_B = 0)		BV_{CEO}*	15		-	Vdc
Collector-Emitter Breakdown Voltage* (R = 10 ohms, I_c = 10mAdc)		BV_{CER}*	20		-	Vdc
Forward-Current Transfer Ratio* (I_c = 10mAdc, V_{CE} = 1Vdc)	2N706 2N706A, 2N706B, 2N753	h_{FE} *	20 20 40	40 40 -	- 60 120	
Base-Emitter Voltage* (I_c = 10mAdc, I_B = 1mAdc)	2N706 2N706A, 2N706B, 2N753	V_{BE} (sat)*	- 0.7	0.75 0.75	0.9 0.9	Vdc
Collector Saturation Voltage* (I_c = 10mAdc, I_B = 1mAdc) (I_c = 50mAdc, I_B = 5mAdc)	2N706, 2N706A 2N706B 2N753 2N753	V_{CE} (sat)*	- - - -	0.3 0.3 0.18 0.3	0.6 0.4 0.6 -	Vdc
Collector Capacitance (V_{CB} = 5Vdc, I_E = 0 (V_{CB} = 10Vdc, I_E = 0)	2N706A, 2N706B, 2N753 2N706	C_{ob}	- -	4.5 5.0	5.0 6.0	pF
Small-Signal Forward Current Transfer Ratio (V_{CE} = 15Vdc, I_E = 10mAdc, f = 100 MHz)		h_{fe}	2.0	4.0	-	-
Current Gain-Bandwidth Product (V_{CE} = 15Vdc, I_E = 10mAdc, f = 100 MHz)		f_T	-	400	-	MHz
Base Resistance (V_{CE} = 15Vdc, I_E = 10mAdc, f = 300 MHz)		r_b	-	39	50	ohms
Charge Storage Time Constant	2N706 2N706A 2N753	τ_s **	- - -	16 16 19	60 25 35	ns
Storage Time	2N706B	t_s	-	19	25	ns
Turn-On Time		t_{on}**	-	30	40	ns
Turn-Off Time		t_{off}**	-	50	75	ns

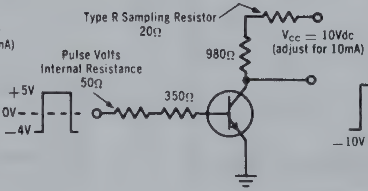
* Pulse Test: PW ≤ 12 ms, Duty Cycle ≤ 2%

** Switching Times Measured with Tektronix Type R Plug-In (50 Ω Internal Impedance) and Circuits Shown Below.

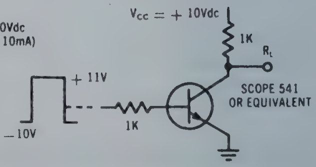
SWITCHING TIME TEST CIRCUIT


Type R Sampling Resistor
20Ω
Pulse Volts
Internal Resistance
200Ω
270Ω
V_{cc} = 3Vdc
(adjust for 10mA)
+ 7V
0V
−2V
1.8K

STORAGE TIME TEST CIRCUIT


Type R Sampling Resistor
20Ω
Pulse Volts
Internal Resistance
50Ω
980Ω
V_{cc} = 10Vdc
(adjust for 10mA)
+5V
0V
−4V
350Ω

MEASUREMENT CIRCUIT


V_{cc} = + 10Vdc
1K
R_L
+ 11V
−10V
1K
SCOPE 541
OR EQUIVALENT

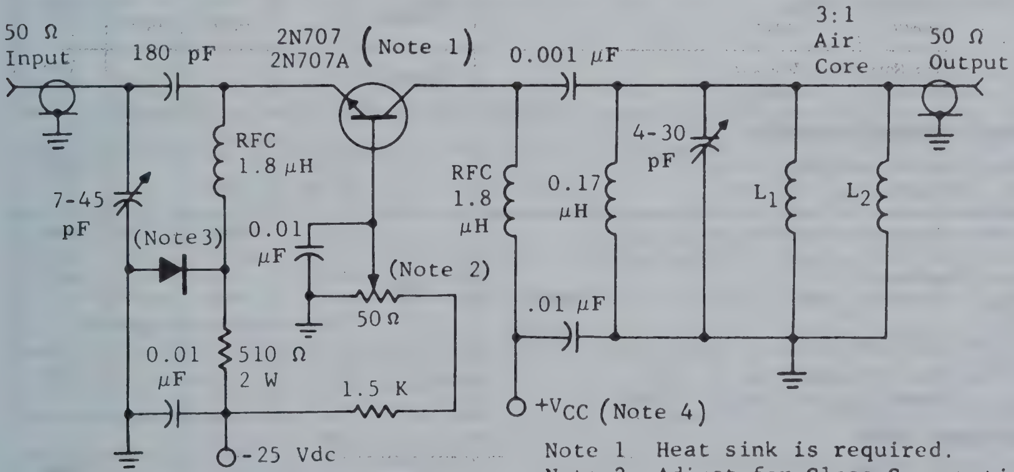
2N707, A (SILICON)

CASE 22
(TO-18)
Collector connected to case

NPN silicon epitaxial mesa transistors for VHF oscillator and class C amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N707	2N707A	Unit
Collector-Emitter Voltage	V_{CEO}	-	40	Vdc
Collector-Emitter Voltage ($R_{BE} \leq$ 10 ohms)	V_{CER}	28	-	Vdc
Collector-Base Voltage	V_{CB}	56	70	Vdc
Emitter-Base Voltage	V_{EB}	4.0	5.0	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	0.3 2.0	0.5 3.33	Watt mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.0 6.67	1.2 8.0	Watts mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		^oC


50 Ω Input
180 pF
2N707
2N707A
(Note 1)
0.001 μF
3:1 Air Core
50 Ω Output
RFC 1.8 μH
7-45 pF
(Note 3)
0.01 μF
(Note 2)
50 Ω
RFC 1.8 μH
0.17 μH
4-30 pF
L1
L2
.01 μF
0.01 μF
510 Ω 2 W
1.5 K
+VCC (Note 4)
-25 Vdc

L_1 5 turns #14 wire wound on 1/2" diameter.

L_2 2 turns #14 wire wound on L_1.

Note 1 Heat sink is required.
Note 2 Adjust for Class C operation.
Note 3 Very High conductance silicon diode.
Note 4 Adjust V_{CC} for proper V_{CE}

FIGURE 1 – 100 MHz, CLASS C, COMMON BASE AMPLIFIER

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage[1] (I_C = 20 mAdc, I_B = 0)	2N707A	BV_{CEO}	40	-	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, R_{BE} = 10 ohms)	2N707	BV_{CER}	28	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N707 2N707A	BV_{CBO}	56 70	- -	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N707A	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 15 Vdc, I_E = 0)	2N707		-	0.005	5.0	
(V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	2N707		-	3.0	-	
(V_{CB} = 30 Vdc, I_E = 0)	2N707A		-	0.01	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N707A		-	5.0	100	
Emitter Cutoff Current		I_{EBO}				μAdc
(V_{BE} = 4 Vdc, I_C = 0)	2N707		-	-	10	
(V_{BE} = 5 Vdc, I_C = 0)	2N707A		-	-	100	
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N707 2N707A	h_{FE}	9.0 9.0	12 -	- 50	-
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{CE(sat)}$	-	0.18	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	-	0.75	0.9	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 15 mAdc, V_{CE} = 10 Vdc)		f_T	70	350	-	MHz
Maximum Frequency of Oscillation		f_{max}	-	600	-	MHz
Output Capacitance		C_{ob}				pF
(V_{CB} = 10 Vdc, I_E = 0)	2N707		-	4.0	10.0	
(V_{CB} = 5 Vdc, I_E = 0)	2N707A		-	4.0	6.0	
Collector-Base Time Constant (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 4 MHz)		$r'_b C_c$	-	80	-	ps
FUNCTIONAL TEST						
Power Output (Figure 1)		P_{out}				mW
(V_{CE} = 20 Vdc, P_{in} = 50 mW)	All Types		200	300	-	
(V_{CE} = 40 Vdc, P_{in} = 175 mW)	2N707A		400	-	-	
100-MHz Oscillator Efficiency (V_{CE} = 28 Vdc, I_C = 40 mAdc)		η	-	38	-	%

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N708 (SILICON)

2N708

JAN, JTX AVAILABLE

CASE 22
(TO-18)
Collector
connected to case

NPN silicon annular transistor for high-speed switching applications.

***MAXIMUM RATINGS**

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	360 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ $T_C = 100^oC$ Derate above 25°C Derate above 100°C	P_D	1.2 680 6.9 6.9	Watts mW mW/°C mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−65 to +200	°C

*Indicates JEDEC Registered Data.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	15	-	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, $R_{BE} \leqq$ 10 ohms)	BV_{CER}	20	-	-	Vdc
* Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
* Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
† Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0.25 Vdc, T_A = +125°C)	I_{CEX}	-	-	10	μAdc
* Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.005 -	0.025 15	μAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	-	0.08	μAdc
ON CHARACTERISTICS					
* DC Current Gain (I_C = 0.5 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (Note 1) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (Note 1)	h_{FE}	15 30 15	- - -	- 120 -	-
* Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C to +125°C)	$V_{CE(sat)}$	- -	0.2 -	0.4 0.4	Vdc
* Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C)	$V_{BE(sat)}$	0.72 -	- -	0.80 0.90	Vdc
DYNAMIC CHARACTERISTICS					
†† Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	450	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, 100 kHz $\leqq$ f $\leqq$ 1.0 MHz)	C_{ob}	-	3.0	6.0	pF
* Extrinsic Base Resistance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 300 MHz)	r_b'	-	-	50	ohms
* Storage Time ($I_C = I_{B1} = I_{B2}$ = 10 mAdc)	t_s	-	15	25	ns

*Indicates JEDEC Registered Data.
†JEDEC Registration Defined as V_{CB} = 20 Vdc.
††JEDEC Registration Defined as h_{fe}.
Note 1: Pulse Test: Pulse Width $\leqslant$ 300 μs, Duty Cycle $\leqslant$ 2.0%.

2N711, A, B (GERMANIUM)

CASE 22
(TO-18)
Collector
connected to case

PNP germanium mesa transistors for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N711	2N711A	2N711B	Unit
Collector-Base Voltage	V_{CB}	12	15	18	Vdc
Collector-Emitter Voltage	V_{CES}	12	14	15	Vdc
Collector-Emitter Voltage	V_{CEO}	—	7.0	7.0	Vdc
Emitter-Base Voltage	V_{EB}	1.0	1.5	2.0	Vdc
Collector Current (Continuous)	I_C	50	100	100	mAdc
Emitter Current (Continuous)	I_E	50	100	100	mAdc
Junction Temperature	T_J	← 100 →			°C
Storage Temperature	T_{stg}	← -65 to + 100 →			°C
Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 300 → ← 4.0 →			mW mW/°C
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	← 150 → ← 2.0 →			mW mW/°C

2N711,A,B (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Sym	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 100 μAdc, I_E = 0)	2N711		12	—	—	
	2N711A		15	—	—	
(I_C = 20 μAdc, I_E = 0)	2N711B		18	—	—	
Collector-Emitter Breakdown Voltage		BV_{CES}				Vdc
(I_C = 100 μAdc)	2N711		12	—	—	
	2N711A		14	—	—	
(I_C = 20 μAdc)	2N711B		15	—	—	
Collector-Emitter Breakdown Voltage		BV_{CEO}				Vdc
(I_C = 5 mAdc, I_B = 0)	2N711A, 2N711B		7.0	—	—	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 0.1 mAdc, I_C = 0)	2N711		1.0	—	—	
	2N711A		1.5	—	—	
	2N711B		2.0	—	—	
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 5 Vdc, I_E = 0)	2N711		—	0.2	3.0	
	2N711A		—	—	1.5	
(V_{CB} = 10 Vdc, I_E = 0)	2N711B		—	—	1.5	
Emitter-Base Cutoff Current		I_{EBO}				μAdc
(V_{EB} = 1 Vdc)	2N711A		—	—	100	
	2N711B		—	—	20	
DC Current Gain		h_{FE}				—
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc)	2N711		20	30	—	
	2N711A		25	—	150	
	2N711B		30	—	150	
(I_C = 50 mAdc, V_{CE} = 0.7 Vdc)	2N711A, 2N711B		40	—	—	
Collector Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 0.5 mAdc)	2N711		—	0.2	0.5	
	2N711A		—	—	0.30	
(I_C = 10 mAdc, I_B = 0.4 mAdc)	2N711B		—	—	0.25	
(I_C = 50 mAdc, I_B = 2 mAdc)	2N711A		—	—	0.55	
	2N711B		—	—	0.45	
Small-Signal Current Gain		h_{fe}				—
(I_C = 10 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	2N711A, 2N711B		1.5	—	—	
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc, f = 100 MHz)	2N711A		1.1	—	—	
	2N711B		1.2	—	—	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 10 mAdc, I_B = 0.4 mAdc)	2N711, 2N711A		0.30	0.38	0.44	
	2N711B		0.30	—	0.44	
(I_C = 50 mAdc, I_B = 2 mAdc)	2N711A		0.40	—	0.65	
	2N711B		0.40	—	0.65	
Collector Output Capacitance		C_{ob}				pF
(V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	2N711A, 2N711B		—	—	6.0	
(V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	2N711		—	5.0	—	
Fall Time		t_f				ns
Figure 1:	2N711A		—	—	150	
	2N711B		—	—	110	
Figure 2:	2N711A		—	—	110	
	2N711B		—	—	100	
	2N711		—	90	150	
Minority Carrier Storage Time		t_s				ns
Figure 1:	2N711A		—	—	150	
	2N711B		—	—	140	
Figure 2:	2N711A		—	—	120	
	2N711B		—	—	100	
	2N711		—	90	200	
Delay Plus Rise Time		$t_d + t_r$				ns
Figure 1:	2N711A, 2N711B		—	—	100	
Figure 2:	2N711A, 2N711B		—	—	75	
	2N711		—	70	100	

SWITCHING CIRCUITS

FIGURE 1

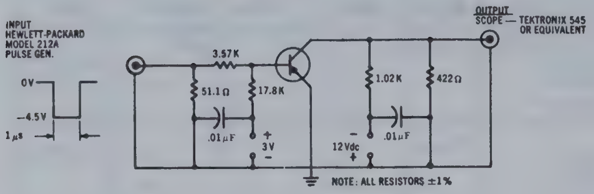
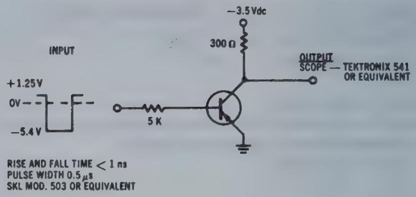
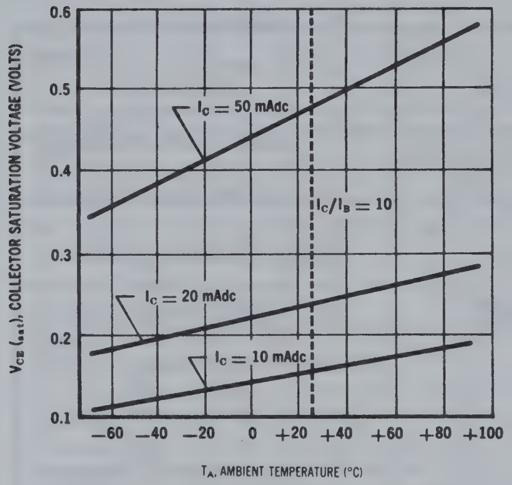

INPUT
HEWLETT-PACKARD
MODEL 212A
PULSE GEN.
0V
−4.5V
1 µs
3.57 K
51.1 Ω
17.8 K
.01 µF
+
3V
−
OUTPUT
SCOPE — TEKTRONIX 545
OR EQUIVALENT
1.02 K
422 Ω
−
12 Vdc
+
.01 µF
NOTE: ALL RESISTORS ±1%

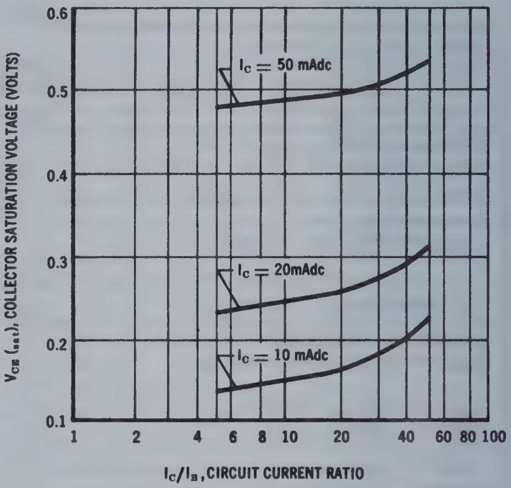
FIGURE 2


−3.5 Vdc
300 Ω
INPUT
+1.25V
0V
−5.4V
5 K
OUTPUT
SCOPE — TEKTRONIX 541
OR EQUIVALENT
RISE AND FALL TIME < 1 ns
PULSE WIDTH 0.5 µs
SKL MOD. 503 OR EQUIVALENT

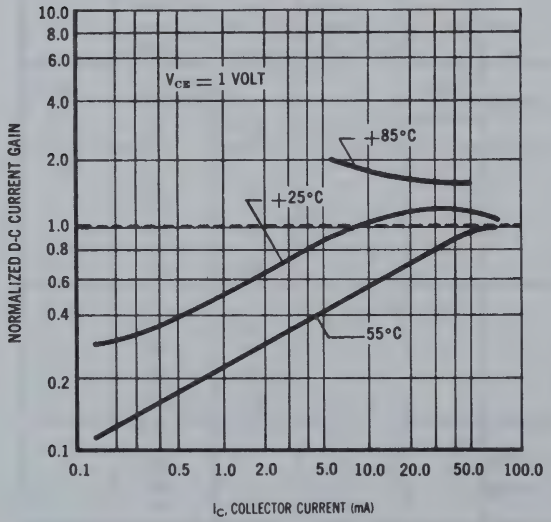
COLLECTOR SATURATION VOLTAGE versus AMBIENT TEMPERATURE



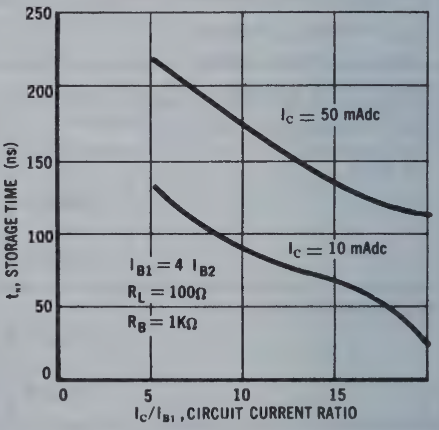
COLLECTOR SATURATION VOLTAGE STORAGE TIME versus CIRCUIT CURRENT RATIO



NORMALIZED DC CURRENT GAIN versus COLLECTOR CURRENT



STORAGE TIME versus CIRCUIT CURRENT RATIO



2N718 (SILICON)
2N1420

2N718
CASE 22
(TO-18)

2N1420
CASE 31
(TO-5)

Collector connected to case

NPN silicon annular Star transistors for medium-current switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CER}			Vdc
2N718		40		
2N1420		30		
Emitter-Base Voltage	V_{EB}	5.0		Vdc
		2N1420 TO-5	2N718 TO-18	
Total Device Dissipation at 25°C Case Temperature	P_D	3.0	1.5	Watts
Derating Factor Above 25°C		20	10	mW/°C
Total Device Dissipation at 25°C Ambient Temperatures	P_D	0.6	0.4	Watts
Derating Factor Above 25°C		4.0	2.66	mW/°C
Junction Temperature	T_J	+ 175		°C
Storage Temperature range	T_{stg}	-65 to + 200		°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current	I_{CBO}				µAdc
(V_{CB} = 30 Vdc, I_E = 0)		–	.001	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		–	–	100	
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_E = 0)	BV_{CBO}	60	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed; $R_B \leqq$ 10 Ohms)	BV_{CER}				Vdc
2N718		40	–	–	
2N1420		30	–	–	
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	–	0.3	1.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	–	–	1.3	Vdc

(1) **Pulse Test: PW $\leqq$ 300 µs, Duty Cycle $\leqq$ 2%**

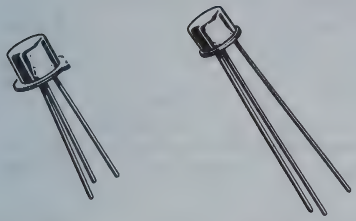
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
DC Forward Current Transfer Ratio (1)	h_{FE}				—
(I_C = 1 mAdc, V_{CE} = 10 Vdc)					
2N718		—	20	—	
2N1420		—	35	—	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)					
2N718		40	—	120	
2N1420		100	—	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)					
2N718		—	20	—	
2N1420		—	35	—	
Small Signal Forward Current Transfer Ratio (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	h_{fe}	2.5	15	—	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	—	5.0	35	pF

(1) **Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%**

2N718A (SILICON)

2N718A JAN, JTX AVAILABLE
2N956
2N1613
2N1613 JAN AVAILABLE



CASE 22
(TO-18)
2N718A
2N956

CASE 31
(TO-5)
2N1613
2N1711

Collector connected to case

NPN silicon annular Star transistors for high-speed switching and DC to UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N718A 2N956	2N1613 2N1711	Unit
Collector-Emitter Voltage	V_{CER}	50		Vdc
Collector-Base Voltage	V_{CB}	75		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.86	800 4.57	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10.3	3.0 17.1	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

2N718A, 2N956, 2N1613, 2N1711 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed; R_{BE} ≤ 10 ohms)		BV_{CER}	50	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	75	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	7.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	-	0.001	0.01	μAdc
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)			-	-	10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	2N718A, 2N1613	I_{EBO}	-	-	0.010	μAdc
	2N956, 2N1711		-	-	0.005	
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.01 mAdc, V_{CE} = 10 Vdc)	2N956, 2N1711	h_{FE}	20	-	-	-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		35	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N718A, 2N1613		35	-	-	
	2N956, 2N1711		75	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		35	-	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*	2N718A, 2N1613		40	-	120	
	2N956, 2N1711		100	-	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)*	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		40	-	-	
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	-	0.24	1.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$	-	1.0	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N718A, 2N1613	f_T	60	300	-	MHz
	2N956, 2N1711		70	300		
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	4.0	25	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	20	80	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	24	-	34	ohms
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			4.0	-	8.0	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N718A, 2N1613	h_{rb}	-	-	3.0	X 10^{-4}
	2N956, 2N1711		-	-	5.0	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613		-	-	3.0	
	2N956, 2N1711		-	-	5.0	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N718A, 2N1613	h_{fe}	30	-	100	-
	2N956, 2N1711		50	-	200	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613		35	-	150	
	2N956, 2N1711		70	-	300	
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	0.1	-	0.5	μmho
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			0.1	-	1.0	
Noise Figure (I_C = 300 μAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613	NF	-	-	12	dB
	2N956, 2N1711		-	-	8.0	

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N720A (SILICON)

CASE 22
(TO-18)
Collector connected to case

NPN silicon annular transistor designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Emitter Voltage	V_{CER}	100	Vdc
Collector-Base Voltage	V_{CB}	120	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.5 2.86	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.8 10.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	97	°C/W

2N720A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	80	-	Vdc
Collector-Emitter Sustaining Voltage (1) (I_C = 100 mAdc, R_{BE} = 10 ohms)	$BV_{CER(sus)}$	100	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	120	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0)	I_{CBO}	-	.010	μAdc
(V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)		-	15	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	.010	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	-	-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)*		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*		40	120	
Collector-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	-	1.2	Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	5.0	
Base-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	1.3	
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	Ohms
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		4.0	8.0	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	1.25	$X 10^{-4}$
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	1.50	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	30	100	-
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		45	-	
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.5	μmhos
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	0.5	

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N721 (SILICON)

CASE 22
(TO-18)

Collector connected to case

PNP silicon annular transistor for high-frequency general-purpose amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Collector-Emitter Voltage	V_{CER}	50	Vdc
Collector - Base Voltage	V_{CB}	50	Vdc
Emitter - Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ T_A=25°C (Derate above 25°C)	P_D	0.40 2.67	Watts mW/°C
Total Device Dissipation @ T_C=25°C T_C=100°C (Derate above 25°C)	P_D	1.5 0.75 10	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

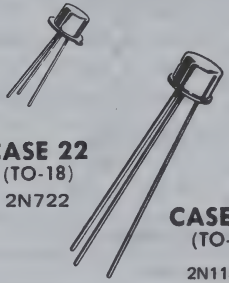
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage*	$BV_{CEO(sus)}$*			Vdc
(I_C = 100 mAdc, I_B = 0)		35	-	
Collector-Emitter Sustaining Voltage*	$BV_{CER(sus)}$*			Vdc
(I_C = 100 mAdc, $R_{BE} \leq$ 100 ohms)		50	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 100 µAdc, I_E = 0)		50	-	
Collector Cutoff Current	I_{CBO}			µAdc
(V_{CB} = 30 Vdc, I_E = 0)		-	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		-	100	
Emitter Cutoff Current	I_{EBO}			µAdc
(V_{BE} = 2.0 Vdc, I_C = 0)		-	100	
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			
(I_C = 150 mAdc, V_{CE} = 10 Vdc)		20	45	-
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc)		15	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	1.5	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	1.3	
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product	f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)		50	-	
Output Capacitance	C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		-	45	
Input Capacitance	C_{ib}			pF
(V_{BE} = 0.5 Vdc, I_C = 0)		-	100	
Input Impedance	h_{ib}			ohms
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		25	35	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	10	
Voltage Feedback Ratio	h_{rb}			
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		-	8.0	$X10^{-4}$
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	8.0	
Small Signal Current Gain	h_{fe}			
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		15	50	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		20	-	
Output Admittance	h_{ob}			µmhos
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		-	1.0	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)		-	5.0	

* Pulse Test: Pulse Width = 300 µs; Duty Cycle = 1.0%

2N722 (SILICON)
(2N1132 JAN AVAILABLE)
2N1132
2N1132A
2N2303

PNP SILICON SWITCHING TRANSISTORS



CASE 22
(TO-18)
2N722

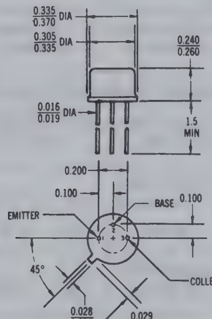
CASE 31
(TO-5)
2N1132
2N1132A
2N2303

PNP SILICON ANNULAR TRANSISTORS

. . . designed for medium-current switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N722	2N1132	2N1132A	2N2303	Unit
Collector-Emitter Voltage	V_{CEO}	35	35	40	35	Vdc
Collector-Emitter Voltage ($R_{BE} \leq 10$ Ohms)	V_{CER}	50	50	50	50	Vdc
Collector-Base Voltage	V_{CB}	50	50	60	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	5.0	5.0	Vdc
Collector Current	I_C	-	-	600	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	400 2.67	600 4.0	600 4.0	600 4.0	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.5 10	2.0 13.3	2.0 13.3	2.0 13.3	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175				°C
Storage Temperature Range	T_{stg}	-65 to +300				°C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0.305
0.335 DIA
0.240
0.260
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0.019 DIA
1.5
MIN
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0.100
BASE
0.100
EMITTER
45°
COLLECTOR
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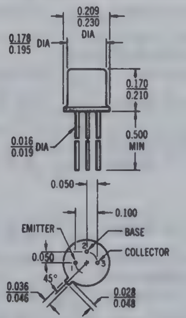
0.034
0.029
0.045

TO-5 OUTLINE
(Collector internally connected to case)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0.230
DIA
0.178
0.195 DIA
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0.500
MIN
0.050
0.100
EMITTER
BASE
COLLECTOR
0.050
45°
0.036
0.046
0.028
0.048

TO-18 OUTLINE
(Collector internally connected to case)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage [(1)]		BV_{CEO}			Vdc
(I_C = 100 mAdc, I_B = 0)	2N722, 2N1132, 2N2303		35	-	
	2N1132A		40	-	
Collector-Emitter Breakdown Voltage [(1)]		BV_{CER}			Vdc
(I_C = 100 mAdc, R_{BE} ≤ 10 Ohms)			50	-	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 100 μAdc, I_E = 0)	2N722, 2N1132, 2N2303		50	-	
	2N1132A		60	-	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 100 μAdc, I_C = 0)	2N722, 2N1132, 2N2303		5.0	-	
(I_E = 1.0 mAdc, I_C = 0)	2N1132A		5.0	-	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)	2N722, 2N1132, 2N2303		-	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N722, 2N1132, 2N2303		-	100	
(V_{CB} = 50 Vdc, I_E = 0)	2N1132A		-	0.5	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	2N1132A		-	50	
Emitter Cutoff Current		I_{EBO}			μAdc
(V_{BE} = 5.0 Vdc, I_C = 0)	2N1132A		-	100	
(V_{BE} = 2.0 Vdc, I_C = 0)	2N2303		-	100	

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain		h_{FE}			-
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc)	2N722, 2N1132, 2N1132A		25	-	
	2N2303		75	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N722, 2N1132, 2N1132A		30	90	
	2N2303		75	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			-	1.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			-	1.3	

SMALL-SIGNAL CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)			60	-	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N722, 2N1132, 2N2303		-	45	
(V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	2N1132A		-	30	
Input Capacitance		C_{ib}			pF
(V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)			-	80	
Input Resistance		h_{ib}			Ohms
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)			25	35	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			-	10	
Voltage Feedback Ratio		h_{rb}			X 10^{-4}
(I_C = 1.0 Adc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)			-	8.0	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)			-	8.0	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N722, 2N1132		25	100	
	2N1132A		25	75	
	2N2303		75	300	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N722, 2N1132, 2N1132A		30	-	
	2N2303		75	-	
Output Admittance		h_{ob}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)			-	1.0	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)			-	5.0	

---

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N726 (SILICON)
2N727

PNP SILICON ANNULAR TRANSISTORS

. . . designed for general purpose audio amplifier applications.

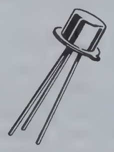
- Collector-Emitter Breakdown Voltage —
  BV_{CEO} = 20 Vdc (Min) @ I_C = 10 mAdc
- Low Output Capacitance —
  C_{ob} = 5.0 pF (Max) @ V_{CB} = 5.0 Vdc

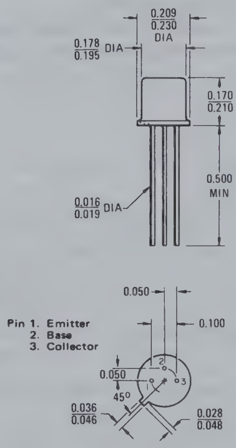
*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 2.0	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.0 6.67	Watt mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	^oC

*Indicates JEDEC Registered Data

PNP SILICON AMPLIFIER TRANSISTORS




0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
Pin 1. Emitter
2. Base
3. Collector
2
1
3
0.050
45°
0.036
0.046
0.028
0.048

Collector Connected to Case
CASE 22 (1)
(TO-18)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	20	–	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, I_B = 0)	I_{CEO}	–	5.0	μAdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 25 Vdc, I_E = 0)		–	1.0	
(V_{CB} = 25 Vdc, I_E = 0, T_A = 150°C)		–	25	
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	I_{EBO}	–	0.5	μAdc
ON CHARACTERISTICS				
DC Current Gain(1)	h_{FE}			–
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc) 2N726		15	45	
2N727		30	120	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = −55°C) 2N726		6.0	–	
2N727		12	–	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	–	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	–	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	140	–	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	–	5.0	pF
Small-Signal Current Gain	h_{fe}			–
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N726		15	90	
2N727		30	240	

*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2.0%.

(2) f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N731 (SILICON)

CASE 22
(TO-18)

Collector electrically connected to case

NPN silicon transistor designed primarily for medium-power audio-frequency applications in industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (R_{BE} = ≦ 10 ohms)	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	0.5 3.33	Watt mW/° C
Total Device Dissipation @ T_C = 25° C Derate above 25° C	P_D	1.5 10	Watts mW/° C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 100 mAdc, R_{BE} = 10 ohms)	BV_{CER}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150° C)	I_{CBO}	 - -	 1.0 100	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 150 mAdc, V_{CE} = 10 Vdc)	h_{FE}	40	120	-
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	1.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	25	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	35	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	80	pF

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

2N735 (SILICON)
2N736
2N739
2N740

CASE 22
(TO-18)
Collector connected to case

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N735 2N736	2N739 2N740	Unit
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector-Base Voltage	V_{CB}	80	125	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.86		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

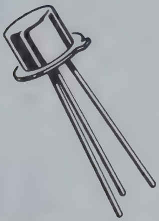
Lead Temperature, 1/16" ± 1/32" from case for 10 s.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)	2N735, 2N736 2N739, 2N740	BV_{CEO}	60 80	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N735, 2N736 2N739, 2N740	BV_{CBO}	80 125	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)		I_{CBO}	-	1.0	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	10	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc)	2N735, 2N739 2N736, 2N740	h_{FE}	30 60	100 200	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 2.0 mAdc)		$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 2.0 mAdc)		V_{BE}	0.35	1.5	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	-	10	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N735, 2N739 2N736, 2N740	h_{ie}	- -	1500 1800	Ohm
Small-Signal Current Gain (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 Hz)	2N735, 2N739 2N736, 2N740	h_{fe}	40 80	100 200	-

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N741, A (GERMANIUM)



CASE 22
(TO-18)

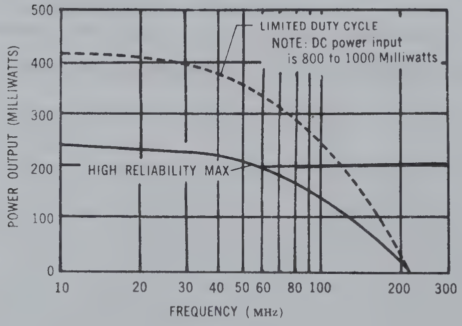
Collector connected to case

PNP germanium mesa transistors for oscillator, frequency multiplier and amplifier applications.

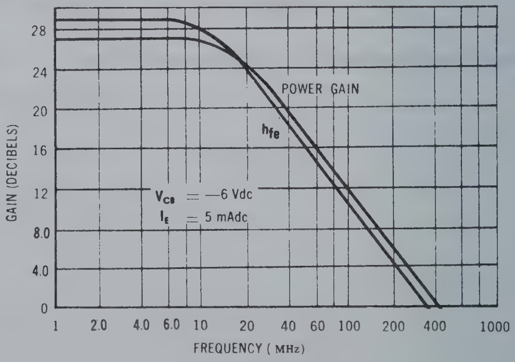
MAXIMUM RATINGS

Rating	Symbol	2N741	2N741A	Unit
Collector-Emitter Voltage	V_{CE}	15	20	Vdc
Collector-Base Voltage	V_{CB}	15	20	Vdc
Emitter-Base Voltage	V_{EB}	1.0		Vdc
Collector Current	I_C	100		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0		mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

POWER OUTPUT versus FREQUENCY, CLASS C AMPLIFIER



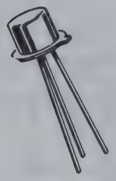
POWER GAIN AND COMMON EMITTER CURRENT GAIN versus FREQUENCY



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N741 2N741A	BV_{CBO}	15 20	- -	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	1.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0) (V_{CE} = 20 Vdc, V_{BE} = 0)	2N741 2N741A	I_{CES}	- -	- -	100 100	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	0.2	3.0	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 5 mAdc, V_{CE} = 6 Vdc)		h_{FE}	10	25	-	-
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 100 MHz)	2N741 2N741A	f_T	- 300	360 360	- -	MHz
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	6.0	10	pF
Collector Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 100 kHz)		C_c	-	3.0	-	pF
Small-Signal Current Gain (I_C = 5 mAdc, V_{CE} = 6 Vdc, f = 1 kHz)		h_{fe}	20	-	-	-
Output Admittance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 1 kHz)		h_{ob}	-	45	-	μmhos
Input Impedance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 1 kHz)		h_{ib}	-	8.0	15	Ohms
Base Resistance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 300 MHz)	2N741 2N741A	r'_b	- -	75 65	- -	Ohms
Noise Figure (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 30 MHz)		NF	-	7.0	-	dB
Power Gain, Matched, Neutralized (V_{CB} = 6 Vdc, I_E = 5 mAdc, f = 30 MHz)		G_{pe}	16	22	-	dB
Power Output (I_C = 60 mAdc, V_{CB} = 6 Vdc, G_{pe} = 8 dB, f = 30 MHz)		P_{out}	- -	200 250	- -	mW
Power Output (I_C = 60 mAdc, V_{CB} = 6 Vdc, G_{pe} = 5 dB, f = 70 MHz)		P_{out}	-	200	-	mW

2N743 (SILICON)



NPN silicon annular transistor designed for high-speed, low-current, saturated switching operations.

CASE 22
(TO-18)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	200	mAdc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	300 1.71	mW mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	° C

SWITCHING TEST CIRCUITS

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

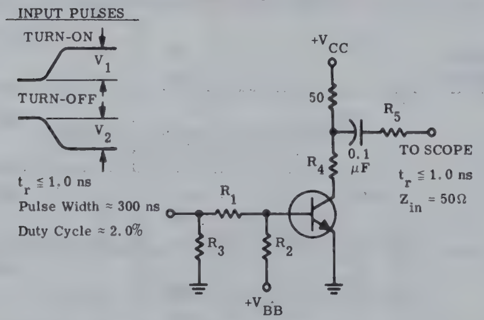
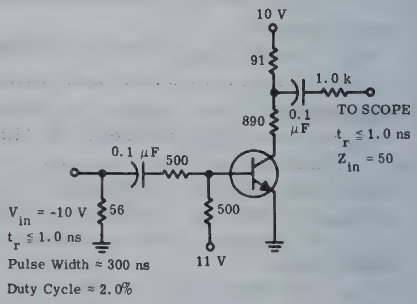

INPUT PULSES
TURN-ON
V_1
TURN-OFF
V_2
$t_r \leq 1.0$ ns
Pulse Width ≈ 300 ns
Duty Cycle ≈ 2.0%
$+V_{CC}$
50
R_5
R_4
0.1 μF
TO SCOPE
$t_r \leq 1.0$ ns
$Z_{in} = 50\Omega$
R_1
R_3
R_2
$+V_{BB}$

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT


10 V
91
1.0 k
0.1 μF
TO SCOPE
$t_r \leq 1.0$ ns
$Z_{in} = 50$
890
0.1 μF
500
$V_{in} = -10$ V
56
500
$t_r \leq 1.0$ ns
Pulse Width ≈ 300 ns
Duty Cycle ≈ 2.0%
11 V

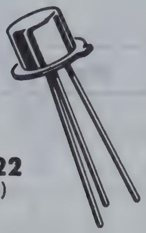
CIRCUIT CONDITIONS									
	(VOLTS)					(OHMS)			
	t_{on}		t_{off}						
Condition	V_1	V_{BB}	V_2	V_{BB}	V_{CC}	$R_1 = R_2$	R_3	R_4	R_5
1	15	-3.0	-15	+12	3.0	3.3 k	50	220	-
2	20	-4.5	-20	+15.3*	6.0	330	56	-	1.0 k

* V_{BB} is pulsed for 1.5 s at less than 10% Duty Cycle to maintain $T_C < 30°C$.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	12	-	Vdc
Collector-Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0) (V_{CE} = 20 Vdc, V_{BE} = 0, T_A = 170°C)	I_{CES}	- -	1.0 100	µAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, $V_{EB(off)}$ = 0.35 Vdc, T_A = 100°C)	I_{CEX}	-	30	µAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	1.0	µAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	10	µAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 0.25 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	10 20 10 10	- 60 - -	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 170°C) (I_C = 100 mAdc, I_B = 10 mAdc, T_A = 170°C) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C)	$V_{CE(sat)}$	- - -	0.35 1.0 1.1	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C) (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc, T_A = -55°C)	$V_{BE(sat)}$	0.65 - - -	0.85 1.1 1.5 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	282	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	5.0	pF
Turn-On Time (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, Condition 1) (V_{CC} = 6.0 Vdc, $V_{BE(off)}$ = 2.4 Vdc, I_C = 100 mAdc, I_{B1} = 40 mAdc, Figure 1, Condition 2)	t_{on}	- -	16 12	ns
Turn-Off Time (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc, Condition 1) (V_{CC} = 6.0 Vdc, I_C = 100 mAdc, I_{B1} ≈ 40 mAdc, I_{B2} ≈ 20 mAdc, Figure 1, Condition 2)	t_{off}	- -	24 40	ns
Storage Time (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc, V_{CC} = 10 Vdc, Figure 2)	t_s	-	14	ns

2N744 (SILICON)



CASE 22
(TO-18)

Collector connected to case

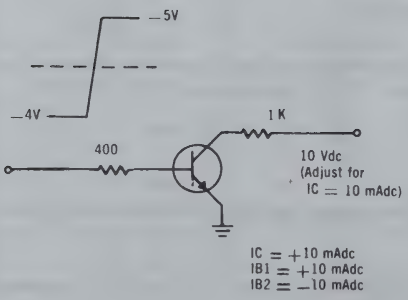
NPN silicon annular transistor for high-speed switching applications.

MAXIMUM RATINGS

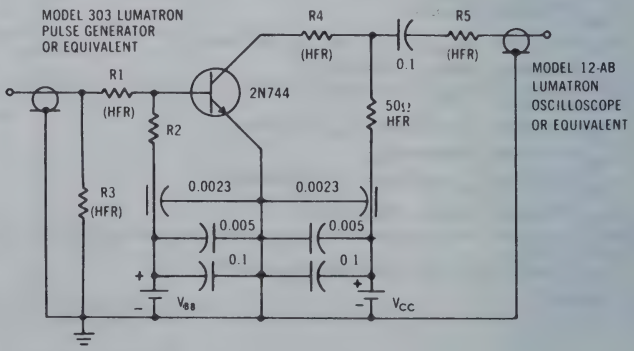
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage*	V_{CEO}	12*	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector DC Current	I_C	200	mAdc
Total Device Dissipation at 25°C Case Temperature (Derate 6.67 mW/°C above 25°C)	P_D	1.0	Watt
Total Device Dissipation at 25°C Ambient Temperature Derate above 25°C	P_D	0.3 2.0	Watt mW/°C
Junction Temperature	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C

*Refers to the voltage at which the magnitude of h_{FE} approaches one when the emitter-base diode is open-circuited.

SWITCHING TIME TEST CIRCUIT


5V
−4V
400
1 K
10 Vdc
(Adjust for
IC = 10 mAdc)
IC = +10 mAdc
IB1 = +10 mAdc
IB2 = −10 mAdc

CHARGE STORAGE TEST CIRCUIT


MODEL 303 LUMATRON
PULSE GENERATOR
OR EQUIVALENT
R1
(HFR)
R2
R3
(HFR)
2N744
R4
(HFR)
0.1
R5
(HFR)
50Ω
HFR
MODEL 12-AB
LUMATRON
OSCILLOSCOPE
OR EQUIVALENT
0.0023
0.0023
0.005
0.005
0.1
0 1
+
−
VBB
+
−
VCC

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CE} = 20 Vdc, I_E = 0) (V_{CE} = 20 Vdc, I_B = 0, T_A = 170°C)	I_{CES}	 – –	 .005 –	 1.0 100	µAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.35 Vdc, T_A = 100°C)	I_{CEX}	–	–	30	µAdc
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	–	–	10	µAdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)*	BV_{CEO}	12	30	–	Vdc
Forward Current Transfer Ratio (I_C = 1.0 mAdc, V_{CE} = 0.25 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)*	h_{FE}	 20 40 20 20	 – – – –	 – 120 – –	–
Small Signal Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	2.8	4.5	–	–
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 10 mAdc, I_B = 1 mAdc, T_A = -55°C) (I_C = 100 mAdc, I_B = 10 mAdc)* (I_C = 100 mAdc, I_B = 10 mAdc, T_A = -55°C) (1)	V_{BE}	 0.7 – – –	 – – – –	 0.85 1.1 1.5 1.6	Vdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc, T_A = 170°C) (I_C = 100 mAdc, I_B = 10 mAdc, T_A = 170°C) (1)	$V_{CE(sat)}$	 – –	 – –	 0.35 1.0	Vdc
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0)	C_{ob}	–	3.0	5.0	pF
Turn-on Time (Condition 1) (Condition 2) (Condition 3) (Condition 4)	t_{on}	 – – – –	 26 10 7.0 6.0	 – 16 – 12	ns
Turn-off Time (Condition 1) (Condition 2) (Condition 3) (Condition 4)	t_{off}	 – – – –	 30 17 18 23	 – 24 – 45	ns
Charge Storage Time Constant (I_C = 10 mAdc, I_{B1} = $-I_{B2}$ = 10 mAdc)	τ_s	–	–	18	ns

(1) Pulse Test: Pulse width ≦ 300 µs, duty cycle ≦ 2%

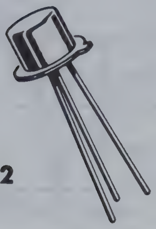
CONDITION	I_C mA	I_{B1} mA	I_{B2} mA	$V_{BE(off)}$ Vdc	V_{CC} Vdc	$R_1 = R_2$ Ω	R_3 Ω	R_4 Ω	R_5 Ω	t_{on}		t_{off}	
										V_{BB} V	V_{IN} V	V_{BB} V	V_{IN} V
1	3	1	-0.5	-0.9	3.4	6.8 K	50	1 K	0	-1.8	10.2	8.4	-10.2
2	10	3	-1.5	-1.5	3.0	3.3 K	50	220	0	-3.0	15.0	12.0	-15.0
3	50	15	-7.5	-1.8	4.0	680	50	18	1 K	-3.5	15.3	*11.7	-15.3
4	100	40	-20.0	-2.4	6.0	330	56	0	1 K	-4.5	20.0	*15.3	-20.0

*V_{BB} is pulsed for 1.5 s @ less than 10% duty cycle

2N753 (SILICON)

For Specifications, See 2N706 Data.

2N827 (GERMANIUM)



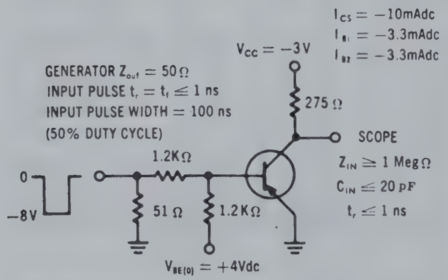
CASE 22
(TO-18)

Collector connected to case

PNP germanium mesa transistor for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage	V_{CES}	20	Vdc
Collector-Emitter Voltage	V_{CEX}	10	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to + 100	°C
Device Dissipation @ 25°C Ambient Temperature (Derate 2mW/°C above 25°C)	P_D	150 2.0	mW mW/°C

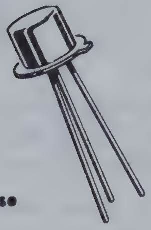

$I_{CS} = -10$mAdc
$I_{B1} = -3.3$mAdc
$I_{B2} = -3.3$mAdc
$V_{CC} = -3V$
GENERATOR $Z_{out} = 50\,\Omega$
INPUT PULSE $t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH = 100 ns
(50% DUTY CYCLE)
275 Ω
SCOPE
$Z_{IN} \geq 1$ Meg Ω
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns
1.2KΩ
0
−8V
51 Ω
1.2KΩ
$V_{BE(0)} = +4$Vdc

SWITCHING TIME TEST CIRCUIT

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	20	22	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{EB} = 0)	BV_{CES}	20	22	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4	5.0	---	Vdc
Collector Latch-up Voltage	LV_{CEX}	10	---	---	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_{CES}	---	0.5	5.0	μAdc
Collector-Base Cutoff Current (V_{CB} = 15 Vdc)	I_{CBO}	---	0.5	5.0	μAdc
DC Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	100	150	---	---
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	$V_{CE(sat)}$	---	0.16	0.25	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	V_{BE}	---	0.39	0.5	Vdc
Small-Signal Forward Current Transfer Ratio (I_C = 10 mA, V_{CE} = 1 V, f = 100 MHz)	h_{fe}	2.5	3.5	---	---
Collector Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)	C_{ob}	---	4.0	9.0	pF
Delay Time	t_d	---	10	15	ns
Rise Time	t_r	---	10	20	ns
Storage Time	t_s	---	15	30	ns
Fall Time	t_f	---	15	30	ns

2N828 (GERMANIUM)



CASE 22
(TO-18)
Collector
connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector-Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	300 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

FIGURE 1 — SWITCHING TIME TEST CIRCUIT

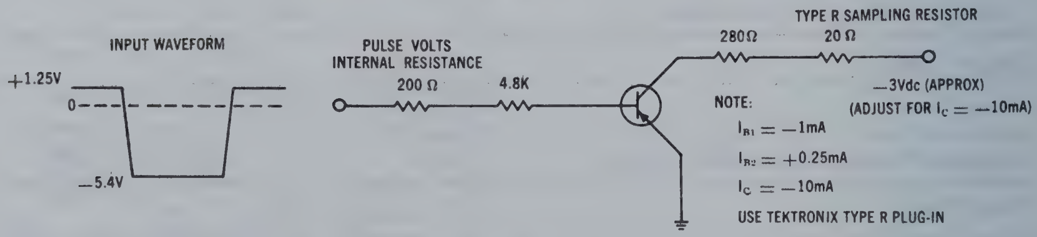

INPUT WAVEFORM
+1.25V
0
—5.4V
PULSE VOLTS
INTERNAL RESISTANCE
200 Ω
4.8K
280Ω
TYPE R SAMPLING RESISTOR
20 Ω
—3Vdc (APPROX)
(ADJUST FOR I_c = —10mA)
NOTE:
I_{B1} = —1mA
I_{B2} = +0.25mA
I_C = —10mA
USE TEKTRONIX TYPE R PLUG-IN

FIGURE 2 — CHARGE STORAGE TIME TEST CIRCUIT

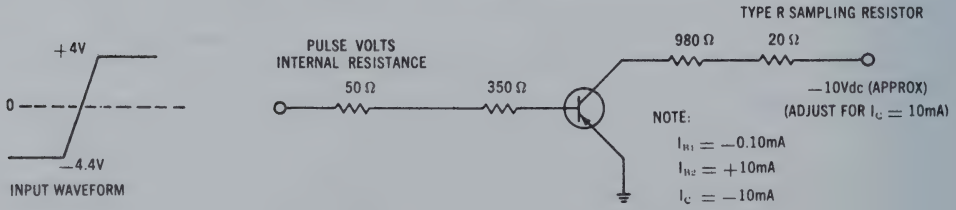

+4V
0
—4.4V
INPUT WAVEFORM
PULSE VOLTS
INTERNAL RESISTANCE
50 Ω
350 Ω
980 Ω
TYPE R SAMPLING RESISTOR
20 Ω
—10Vdc (APPROX)
(ADJUST FOR I_c = 10mA)
NOTE:
I_{B1} = —0.10mA
I_{B2} = +10mA
I_C = —10mA

FIGURE 3 — RISE TIME FACTOR

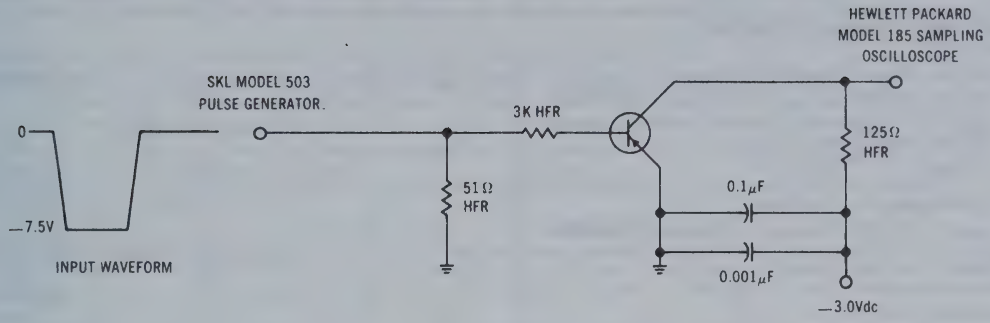
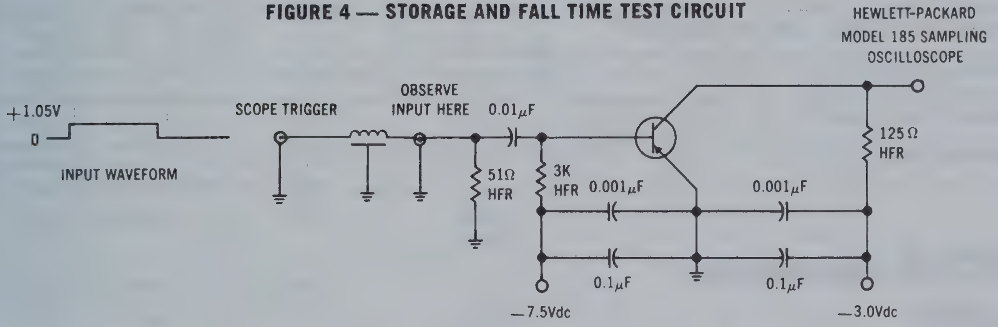

HEWLETT PACKARD
MODEL 185 SAMPLING
OSCILLOSCOPE
SKL MODEL 503
PULSE GENERATOR
0
—7.5V
INPUT WAVEFORM
3K HFR
51 Ω
HFR
125Ω
HFR
0.1μF
0.001μF
—3.0Vdc

FIGURE 4 — STORAGE AND FALL TIME TEST CIRCUIT


HEWLETT-PACKARD
MODEL 185 SAMPLING
OSCILLOSCOPE
+1.05V
0
INPUT WAVEFORM
SCOPE TRIGGER
OBSERVE
INPUT HERE
0.01μF
51Ω
HFR
3K
HFR
0.001μF
0.001μF
125 Ω
HFR
0.1μF
0.1μF
—7.5Vdc
—3.0Vdc

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	-	10	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	15	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100μAdc, I_E = 0)	BV_{CBO}	15	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.5	-	-	Vdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	I_{CBO}	-	0.4	3.0	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	25	40	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)	($V_{CE(sat)}$	- -	0.12 0.18	0.2 0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.34	0.39	0.44	Vdc

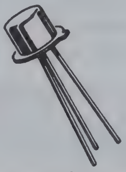
2N828 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	f_T	300	400	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	3.5	-	pF
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	h_{fe}	3	4.0	-	-
Delay Plus Rise Time (Figure 1)	$t_d + t_r$	-	50	70	ns
Storage Time (Figure 1)	t_s	-	33	50	ns
Fall Time (Figure 1)	t_f	-	35	50	ns
Charge Storage Time Constant (Figure 2)	τ_s	-	14	25	ns
Rise Time (Figure 3)	t_r	-	7.0	-	ns
Storage Time (Figure 4)	t_s	-	5.0	-	ns
Fall Time (Figure 4)	t_f	-	3.0	-	ns

2N828A (GERMANIUM)

2N829



CASE 22
(TO-18)

Collector connected to case

PNP germanium epitaxial mesa transistors for high-speed switching applications

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector to Base Voltage	V_{CB}	15	Vdc
Collector to Emitter Voltage	V_{CES}	15	Vdc
Emitter to Base Voltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Total Device Dissipation at 25°C case Temperature (Derate 4.0mw/°C above 25°C)	P_D	300	mW
Total Device Dissipation at 25°C Ambient Temperature (Derate 2.0mw/°C)	P_D	150	mW
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to +100	°C

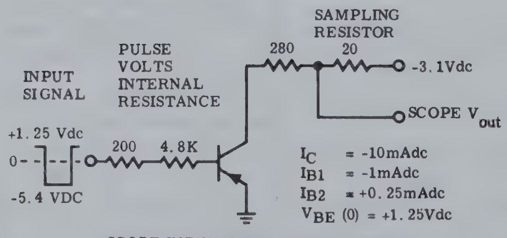
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector to Base Breakdown Voltage $I_E = 0$, I_C = 100 μAdc	BV_{CBO}	15	25	--	Vdc
Collector to Emitter Breakdown Voltage $V_{EB} = 0$, I_C = 100μAdc	BV_{CES}	15	25	--	Vdc
Emitter to Base Breakdown Voltage $I_C = 0$, I_E = 100μ Adc	BV_{EBO}	2.5	--	--	Vdc
Collector Cutoff Current $I_E = 0$, V_{CB} = 6Vdc	I_{CBO}	--	0.4	3.0	μAdc
Forward Current Transfer Ratio I_C = 10mAdc, V_{CE} = 0.3Vdc 2N828A 2N829	h_{FE}	25 50	40 80	--	--
Forward Current Transfer Ratio I_C = 150mAdc, V_{CE} = 1Vdc 2N828A 2N829	h_{fe}	25 50	40 80	--	--
Collector Saturation Voltage I_C = 10mAdc, I_B = 1.0 mAdc 2N828A I_C = 10mAdc, I_B = 0.5mAdc 2N829	$V_{CE(sat)}$	--	0.11 0.11	0.20 0.20	Vdc
Collector Saturation Voltage I_C = 50mAdc, I_B = 5.0mAdc	$V_{CE(sat)}$	--	--	0.25	Vdc
Collector Saturation Voltage I_C = 150mAdc, I_B = 15mAdc 2N828A I_C = 150mAdc, I_B = 7.5mAdc 2N829	$V_{CE(sat)}$	--	0.35 0.38	0.50 0.50	Vdc
Base to Emitter Voltage I_C = 10mAdc, I_B = 1mAdc 2N828A I_C = 10mAdc, I_B = 0.5mAdc 2N829	V_{BE}	0.34 0.30	0.40 0.38	0.44 0.44	Vdc
Base to Emitter Voltage I_C = 150mAdc, I_B = 15mAdc 2N828A I_C = 150mAdc, I_B = 7.5mAdc 2N829	V_{BE}	--	0.70 0.65	0.85 0.85	Vdc
Collector Capacitance $I_E = 0$, V_{CB} = 6Vdc, f = 100 kHz)	C_{ob}	--	2.2	4.0	pF

ELECTRICAL CHARACTERISTICS (continued)

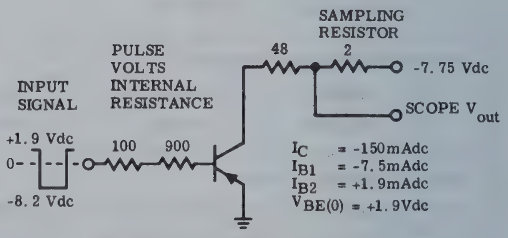
Characteristic	Symbol	Min	Typ	Max	Unit
Input Capacitance V_{BE} = 1Vdc, I_E = 0, f = 100 kHz)	C_{ib}	--	2.2	3.5	pF
Small Signal Forward Current Transfer Ratio I_C = 10mAdc, V_{CE} = -1Vdc, f = 100 MHz	h_{fe}	3.0	4.0	--	--
Current Gain Bandwidth Product V_{CE} = 1Vdc, I_C = -10mAdc, f = 100 MHz	f_T	300	400	--	MHz
Delay Plus Rise Time (Fig. 1) I_C = 10mAdc	td+tr	--	35	50	ns
Storage Time (Fig. 1) I_C = 10mAdc	ts	--	30	50	ns
Fall Time (Fig. 1) I_C = 10mAdc	tf	--	30	50	ns
Total Control Charge (Fig. 3) I_C = 10mAdc	Q_T	--	50	80	pC
Delay Plus Rise Time (Fig. 2) I_C = 150mAdc	t_d+t_r	--	25	50	ns
Turn Off Time (Fig. 2) I_C = 150mAdc	t_{off}	--	60	100	ns
Total Control Charge (Fig. 4) I_C = 150mAdc	Q_T	--	120	175	pC

FIGURE 1 — 10mA SWITCHING TIME TEST CIRCUIT


SAMPLING RESISTOR
PULSE VOLTS INTERNAL RESISTANCE
INPUT SIGNAL
280
20
-3.1Vdc
SCOPE V out
+1.25 Vdc
0-
-5.4 VDC
200
4.8K
IC = -10mAdc
IB1 = -1mAdc
IB2 = +0.25mAdc
VBE (0) = +1.25Vdc

SCOPE INPUT IMPEDANCE = 1Megohm
SCOPE INPUT CAPACITANCE = 20 pF
GENERATOR OUTPUT IMPEDANCE = 50 ohms
INPUT PULSE t_r = t_f = 2ns

FIGURE 2 — 150mA SWITCHING TIME TEST CIRCUIT


SAMPLING RESISTOR
PULSE VOLTS INTERNAL RESISTANCE
INPUT SIGNAL
48
2
-7.75 Vdc
SCOPE V out
+1.9 Vdc
0-
-8.2 Vdc
100
900
IC = -150mAdc
IB1 = -7.5mAdc
IB2 = +1.9mAdc
VBE(0) = +1.9Vdc

SCOPE INPUT IMPEDANCE = 1Megohm
SCOPE INPUT CAPACITANCE = 20 pF
GENERATOR OUTPUT IMPEDANCE = 50 ohms
INPUT PULSE t_r = t_f = 2ns

FIGURE 3 — 10mA TOTAL CONTROL CHARGE TEST CIRCUIT

*ADJUST V_{BB} FOR -5.4 VOLT PULSE AT POINT A

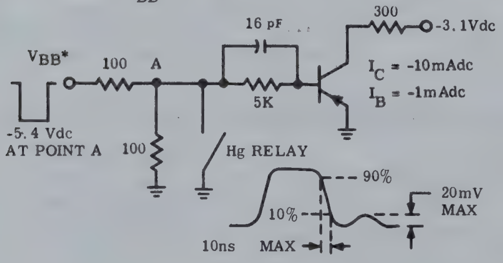
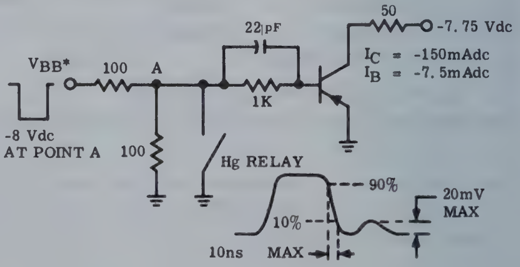

VBB*
100
A
16 pF
5K
300
-3.1Vdc
IC = -10mAdc
IB = -1mAdc
-5.4 Vdc AT POINT A
100
Hg RELAY
90%
10%
20mV MAX
10ns MAX

FIGURE 4 — 150mA TOTAL CONTROL CHARGE TEST CIRCUIT

*ADJUST V_{BB} FOR -8 VOLT PULSE AT POINT A


VBB*
100
A
22 pF
1K
50
-7.75 Vdc
IC = -150mAdc
IB = -7.5mAdc
-8 Vdc AT POINT A
100
Hg RELAY
90%
10%
20mV MAX
10ns MAX

2N834 (SILICON)
2N835

CASE 22
(TO-18)

Collector connected to case

NPN silicon epitaxial transistors for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N834	2N835	Unit
Collector-Emitter Voltage	V_{CES}	30	20	Vdc
Collector-Base Voltage	V_{CB}	40	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	3.0	Vdc
Collector Current-Continuous Peak	I_C	200		mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	0.3 2.0		Watt $mW/^{\circ}C$
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	1.0 6.67		Watt $mW/^{\circ}C$
Total Device Dissipation @ $T_C = 100^{\circ}C$ Derate above $100^{\circ}C$	P_D	0.5 6.67		Watt $mW/^{\circ}C$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		$^{\circ}C$

FIGURE 1 — TURN-ON AND TURN-OFF TIME MEASUREMENT CIRCUIT

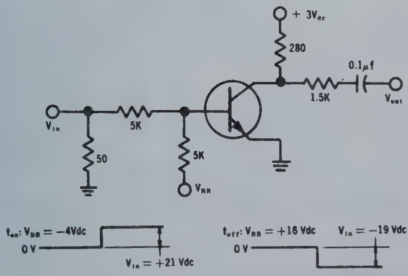
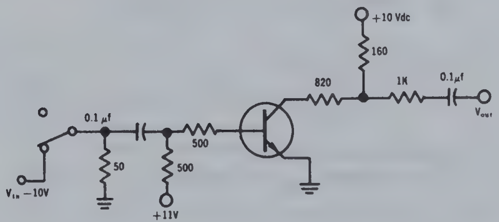

+ 3Vdc
280
0.1μf
1.5K
Vout
Vin
5K
50
5K
VBB
ton: VBB = −4Vdc
0 V
Vin = +21 Vdc
toff: VBB = +16 Vdc
Vin = −19 Vdc
0 V

FIGURE 2 — CHARGE STORAGE TIME CONSTANT MEASUREMENT CIRCUIT


+10 Vdc
160
820
1K
0.1μf
Vout
0.1 μf
500
50
500
+11V
Vin −10V

NOTE: ALL SWITCHING TIMES MEASURED WITH LUMATRON MODEL 420 SWITCHING TIME TEST SET OR EQUIVALENT.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	2N834 2N835	BV_{CBO}	40 25	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	2N834 2N835	BV_{EBO}	5.0 3.0	- -	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0)	2N834	I_{CES}	-	10	µAdc
(V_{CE} = 20 Vdc, V_{BE} = 0)	2N835		-	10	
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	-	0.5	µAdc
(V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)			-	30	
ON CHARACTERISTICS					
DC Current Gain(1) (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N834 2N835	h_{FE}	25 20	- -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	2N834 2N835	$(V_{CE(sat)}$	- -	0.25 0.30	Vdc
(I_C = 50 mAdc, I_B = 5 mAdc)(1)	2N834 2N835		- -	0.4 -	
Base-Emitter Saturation Voltage(1) (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N834	f_T	350	-	MHz
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	2N835		300	-	
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N834	$\|h_{fe}\|$	3.5	-	-
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	2N835		3.0	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	4.0	pF
Charge-Storage Time Constant (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	2N834 2N835	t_s	- -	25 35	ns
Turn-On Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc)	2N834 2N835	t_{on}	- -	33 20	ns
Turn-Off Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc)	2N834 2N835	t_{off}	- -	75 35	ns

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(1) Pulse Test: Pulse Width ≤ 12 ms, Duty Cycle ≤ 2%

2N838 (GERMANIUM)

CASE 22
(TO-18)

Collector connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Emitter Voltage	V_{CEX}	15	Vdc
Emitter-Base Boltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to+ 100	°C
Device Dissipation @ $T_A = 25°C$ (Derate 2mW/°C above 25°C)	P_D	150 2.0	mW mW/°C

FIGURE 1 — SWITCHING TIME TEST CIRCUIT

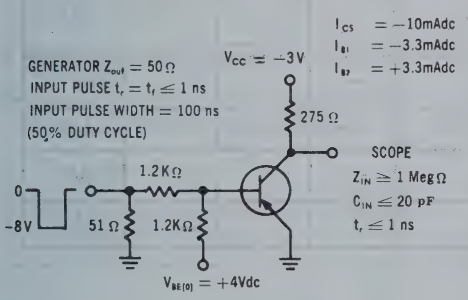
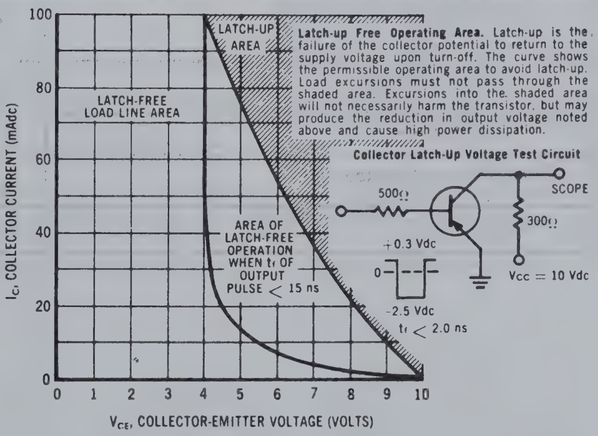

$I_{CS} = -10$mAdc
$I_{B1} = -3.3$mAdc
$I_{B2} = +3.3$mAdc
GENERATOR $Z_{out} = 50\,\Omega$
INPUT PULSE $t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH = 100 ns
(50% DUTY CYCLE)
$V_{CC} = -3$ V
275 Ω
SCOPE
$Z_{IN} \geq 1$ MegΩ
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns
1.2KΩ
0
-8V
51 Ω
1.2KΩ
$V_{BE(0)} = +4$Vdc

FIGURE 2 — AREA OF PERMISSIBLE LOAD LOCI



Latch-up Free Operating Area. Latch-up is the failure of the collector potential to return to the supply voltage upon turn-off. The curve shows the permissible operating area to avoid latch-up. Load excursions must not pass through the shaded area. Excursions into the shaded area will not necessarily harm the transistor, but may produce the reduction in output voltage noted above and cause high power dissipation.

Collector Latch-Up Voltage Test Circuit

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C =100 μAdc, I_E =0)	BV_{CBO}	30	35	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{EB} = 0)	BV_{CES}	30	35	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.5	4.5	---	Vdc
Collector Latch-up Voltage (see Figure 2)	LV_{CEX}	15	---	---	Vdc
Collector-Emitter Cutoff Current (V_{CE} =15 Vdc, V_{EB} =0)	I_{CES}	---	1.0	10	μAdc
Collector-Base Cutoff Current (V_{CB} = 15 V, I_E = 0)	I_{CBO}	---	1.0	10	μAdc
DC Forward Current Transfer Ratio (I_C = 10mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	30	70	---	---
Collector-Emitter Saturation Voltage (I_C =10 mAdc, I_B = 3.3 mAdc)	$V_{CE(sat)}$	---	0.1	0.18	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	V_{BE}	---	0.39	0.5	Vdc
Small-Signal Forward Current Transfer Ratio (I_C = 10 mA, V_{CE} = 1V, f = 100 MHz)	h_{fe}	3.0	4.5	---	---
Collector Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)	C_{ob}	---	2.0	4.0	pF
Delay Time (Figure 1)	t_d	---	10	15	ns
Rise Time (Figure 1)	t_r	---	7.0	15	ns
Storage Time (Figure 1)	t_s	---	10	20	ns
Fall Time (Figure 1)	t_f	---	10	20	ns

2N840 (SILICON)
2N841

CASE 22
(TO-18)

Collector connected to case

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Emitter Voltage	V_{CES}	45	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	2.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.86	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	45	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.0	-	Vdc
Collector Cutoff Current (V_{CE} = 45 Vdc, V_{BE} = 0, R_{BE} = 5.0 k ohms)	I_{CER}	-	20	μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0) (V_{CB} = 45 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	1.0 50	μAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	50	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N840 2N841	h_{FE}	30 60	100 400	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 2.2 mAdc)	$V_{CE(sat)}$	-	2.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 20 MHz) 2N840 2N841	f_T	1.5 2.0	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	15	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N840 2N841 (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz, T_A = -55°C) 2N840 2N841	h_{fe}	40 80 15 25	90 330 - -	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	-	1.2	μmhos
Input Resistance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	-	80	Ohms
Output Conductance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.2	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	$Re(h_{ie})$	-	500	Ohms

2N869 (SILICON)
2N995

CASE 22
(TO-18)

Collector connected to case

PNP silicon annular transistors for high-frequency general-purpose amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Types	Value	Unit
Base Voltage	V_{CB}	2N869 2N995	25 20	Vdc
Collector-Emitter Voltage	V_{CEO}	2N869 2N995	18 15	Vdc
Emitter-Base Voltage	V_{EB}	2N869 2N995	5.0 4.0	Vdc
Total Device Dissipation at 25°C Case Temperature at 100°C Case Temperature Derate above 25°C	P_D	Both Types	 1.2 0.68 6.86	 Watts Watt mW/°C
Total Device Dissipation at 25°C Ambient Temperature Derate above 25°C	P_D	Both Types	 0.36 2.06	 Watt mW/°C
Storage Temperature	T_{stg}	Both Types	-65 to +200	°C
Junction Temperature	T_J	Both Types	+200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}				Vdc
(I_C = 10 μAdc, I_E = 0) 2N869		25	---	---	
2N995		20	---	---	
Collector-Emitter Sustaining Voltage (1)	$V_{CEO(sust)}$				Vdc
(I_C = 10 mAdc, I_B = 0) 2N869		18	---	---	
2N995		15	---	---	
Emitter-Base Breakdown Voltage	BV_{EBO}				
(I_E = 10 μAdc, I_C = 0) 2N869		5.0	---	---	Vdc
2N995		4.0	---	---	
Collector Cutoff Current	I_{CBO}				μ Adc
(V_{CB} = 15 Vdc, I_E = 0) 2N869		---	---	010	
2N995		---	---	005	
(V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C) Both Types		---	---	25	
Emitter Current	I_{EBO}				μ Adc
(V_{EB} = 4.0 Vdc, I_C = 0) 2N995		---	---	10	
Collector Saturation Voltage	V_{CE} (sat)				Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N869		---	0.17	1.0	
(I_C = 20 mAdc, I_B = 2.0 mAdc) 2N995		---	---	0.2	
Base Saturation Voltage	V_{BE} (sat)				Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N869		---	0.78	1.0	
(I_C = 20 mAdc, I_B = 2.0 mAdc) 2N995		---	---	0.95	
DC Forward-Current Transfer Ratio (1)	h_{FE}				---
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N869		20	---	120	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) 2N995		25	---	---	
(I_C = 20 mAdc, V_{CE} = 1.0 Vdc) 2N995		35	---	140	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc) 2N995		25	---	---	
Open-Circuit Output Capacitance	C_{ob}				pF
(V_{CB} = 10 V, I_E = 0) 2N869		---	3.0	9	
2N995		---	3.0	10	
Open-Circuit Input Capacitance	C_{ib}				pF
(V_{BE} = 0.5 V, I_C = 0) Both Types		---	7.0	11	
Small-Signal Forward-Current Transfer Ratio	h_{fe}				---
(I_C = 10 mA, V_{CE} = 15 V, f = 100 MHz) 2N869		1.0	3.0	---	
(I_C = 10 mA, V_{CE} = 10 V, f = 100 MHz) 2N995		1.0	3.0	---	

(1) Pulse Note: Pulse Width = 300 μs, Duty Cycle = 1%

2N869A (SILICON)

2N869A JAN/JANTX Available

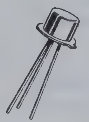
MM869B

PNP SILICON ANNULAR TRANSISTORS

PNP silicon annular low-power transistor designed for medium-speed, saturated switching applications.

- Collector-Emitter Breakdown Voltage —
  BV_{CEO} = 30 Vdc (Min) @ I_C = 10 mAdc — MM869B
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.2 Vdc (Max) @ I_C = 30 mAdc
- Turn-On Time —
  t_{on} = 10 ns (Typ) @ I_C = 30 mAdc — MM869B

PNP SILICON SWITCHING TRANSISTORS

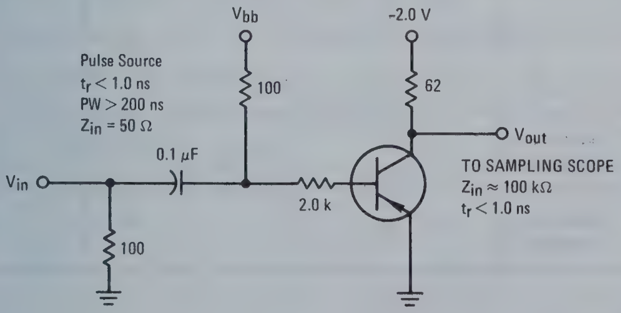


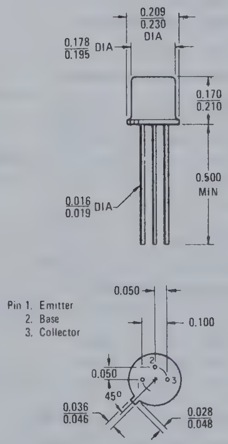
*MAXIMUM RATINGS

Rating	Symbol	2N869A	MM869B	Unit
Collector-Emitter Voltage	V_{CEO}	18	30	Vdc
Collector-Base Voltage	V_{CB}	25	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.1		mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.86		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*2N869A JEDEC Registered Data.

FIGURE 1 — SWITCHING TIME TEST CIRCUIT


V_{bb}
-2.0 V
Pulse Source
$t_r < 1.0$ ns
PW > 200 ns
$Z_{in} = 50\ \Omega$
100
62
V_{out}
0.1 μF
V_{in}
2.0 k
TO SAMPLING SCOPE
$Z_{in} \approx 100$ kΩ
$t_r < 1.0$ ns
100


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
Pin 1. Emitter
2. Base
3. Collector
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

CASE 22 (1)
(TO-18)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

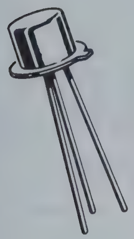
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage(1) (I_C = 10 mAdc, I_B = 0) 2N869A MM869B	$V_{CEO(sus)}$	18 30	– –	– –	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0) 2N869A	BV_{CES}	25	–	–	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0) 2N869A MM869B	BV_{CBO}	25 30	–	– –	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	–	–	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_{CES}	–	–	.010	μAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	–	–	25	μAdc
Base Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_B	–	–	.010	μAdc
ON CHARACTERISTICS					
DC Current Gain(1) (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) (I_C = 10 mAdc, V_{CE} = 5.0 Vdc) (I_C = 30 mAdc, V_{CE} = 0.5 Vdc) (I_C = 30 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE} (1)	30 40 40 17 25	– – – – –	– 120 120 – –	–
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	– – –	– – –	0.15 0.2 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	0.78 0.85 –	– – –	0.98 1.2 1.7	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product(2) (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	f_T	400	–	–	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	–	–	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	–	–	6.0	pF
SWITCHING CHARACTERISTICS					
Turn-On Time (I_C = 30 mAdc, I_{B1} = 1.5 mAdc) Both Types (I_C = 30 mAdc, I_{B1} = 3.0 mAdc) MM829B	t_{on}	– –	– 10	50 –	ns ns
Turn-Off Time (I_C = 30 mAdc, I_{B1} = I_{B2} = 1.5 mAdc) Both Types (I_C = 30 mAdc, I_{B1} = I_{B2} = 3.0 mAdc) MM829B	t_{off}	– –	– 60	80 –	ns ns

*2N869A JEDEC Registered Data.

(1)Pulse Test: Pulse Width = < 300 μs, Duty Cycle < 1.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N910 (SILICON)
2N911



CASE 22
(TO-18)
Collector connected to case

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage	V_{CER}	80	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 2.86	Watt mW/°C
Total Device Dissipation @ T_C = 25°C T_C = 100°C Derate above 25°C	P_D	1.8 0.975 10.3	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

2N910, 2N911 (Continued)

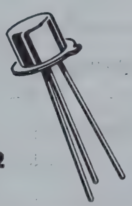
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	60	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, R_{BE} ≦ 10 ohms)	$BV_{CER(sus)}$*	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	100	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0) (V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	25 15	nAdc μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	25	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N910 2N911 (I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N910* 2N911* (I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C) 2N910* 2N911*	h_{FE}	35 20 75 35 30 15	- - - - - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	- -	0.4 1.2	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	0.6 -	0.8 0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz) 2N910 2N911	f_T	60 50	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N910 2N911	h_{ie}	- -	1800 1000	Ohms
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N910 2N911 (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N911	h_{fe}	76 36 40	200 90 100	-
Output Admittance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N910 2N911	h_{oe}	- -	100 50	μmhos
Input Resistance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20 4.0	30 8.0	Ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) 2N910 2N911 (I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) 2N911	h_{rb}	- - -	3.0 1.25 1.75	X 10^{-4}
Output Conductance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz). (I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	- -	0.5 1.0	μmho
Noise Figure (I_C = 0.3 mAdc, V_{CB} = 10 Vdc, R_G = 510 ohms, f = 1.0 kHz, B. W. = 200 Hz) 2N910 2N911	NF	- -	12 15	dB

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle = 2.0%.

2N914 (SILICON)

2N914 JAN, JTX Available



CASE 22
(TO-18)

Collector connected to case

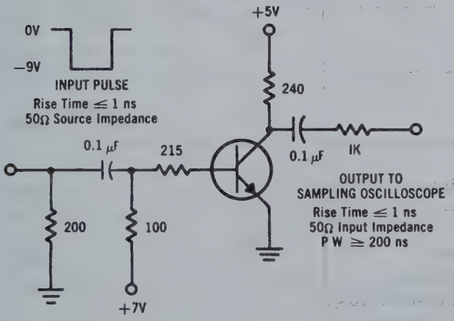
NPN silicon annular transistor for high-speed switching applications.

MAXIMUM RATINGS

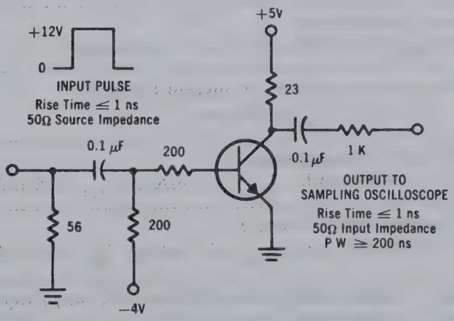
Rating	Symbol	Value	Unit
*Collector-Emitter Voltage	V_{CEO}	15	Vdc
*Collector-Emitter Voltage ($R_{BE} \leq 10$ ohms)	V_{CER}	20	Vdc
*Collector-Base Voltage	V_{CB}	40	Vdc
*Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current (Note 1)	I_C	150	mAdc
*Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	360 2.06	mW mW/^oC
*Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.2 6.9	Watts mW/^oC
*Total Device Dissipation @ $T_C = 100^oC$	P_D	0.68	Watt
*Operating Junction Temperature Range	T_J	200	^oC
*Storage Temperature Range	T_{stg}	-65 to +200	^oC

*Indicates JEDEC Registered Data.
Note 1: Limited by Power Dissipation

CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


0V
−9V
INPUT PULSE
Rise Time ≤ 1 ns
50Ω Source Impedance
+5V
240
0.1 μF
215
0.1 μF
IK
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≤ 1 ns
50Ω Input Impedance
P W ≥ 200 ns
200
100
+7V

t_{on} and t_{off} TEST CIRCUIT


+12V
0
INPUT PULSE
Rise Time ≤ 1 ns
50Ω Source Impedance
+5V
23
0.1 μF
200
0.1 μF
1 K
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≤ 1 ns
50Ω Input Impedance
P W ≥ 200 ns
56
200
−4V

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted.)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
*Collector-Emitter Sustaining Voltage **(Note 1)** (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	15	-	Vdc
*Collector-Emitter Sustaining Voltage **(Note 1)** (I_C = 30 mAdc, $R_{BE} \leq$ 10 ohms)	$BV_{CER(sus)}$	20	-	Vdc
*Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
*Emitter-Base Breakdown Voltage (I_E = 10μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
*Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 125°C)	I_{CEX}	-	10	μAdc
*Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	0.025	μAdc
(V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)		-	15	
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain **(Note 1)** *(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	120	-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)		12	-	
*(I_C = 500 mAdc, V_{CE} = 5.0 Vdc)		10	-	
Collector-Emitter Saturation Voltage **(Note 1)** *(I_C = 200 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	-	0.70	Vdc
(I_C = 10 mAdc, I_B = 1.0 thru 20 mAdc, T_A = -55 to +125°C)		-	0.25	
*Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.70	0.80	Vdc

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
†Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	9.0	pF
*Charge Storage Time Constant **(Note 2)** ($I_C = I_{B1} = I_{B2}$ = 20 mAdc)	τ_s	-	20	ns
Turn-On Time **(Note 2)** (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc)	t_{on}	-	40	ns
Turn-Off Time **(Note 2)** (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc)	t_{off}	-	40	ns

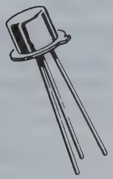
Note 1: Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤1.0%.

Note 2: Measured on Sampling Scope: Pulse Width ≥ 200 ns.

*Indicates JEDEC Registered Data.

†JEDEC Registration Defined as h_{fe}.

2N915 (SILICON)



CASE 22
(TO-18)

Collector connected to case

NPN silicon annular transistor for high-frequency amplifier, oscillator and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	70	Vdc
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	1.2 6.9	W mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.36 2.06	W mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25° C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $I_E = 0$ $V_{CB} = 60V$	I_{CBO}		10	nA
Collector Cutoff Current @ 150°C $I_E = 0$ $V_{CB} = 60V$	I_{CBO}		30	μ A
Collector Breakdown Voltage $I_C = 100\ \mu A$ $I_E = 0$	BV_{CBO}	70		Volts
Collector to Emitter Sustaining Voltage (1) $I_C = 10mA$ $I_B = 0$	V_{CEO}	50		Volts
Emitter Breakdown Voltage $I_C = 0$ $I_E = 100\ \mu A$	BV_{EBO}	5. 0		Volts
Base Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{BE(sat)}$		0. 9	Volts
Collector Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{CE(sat)}$		1. 0	Volts
DC Pulse Current Gain $I_C = 10mA$ $V_{CE} = 5.0V$	h_{FE}	50	200	
Output Capacitance $I_E = 0$ $V_{CB} = 10V$	C_{ob}		3. 5	pF
Emitter Transition Capacitance $I_C = 0$ $V_{EB} = 0.5V$	C_{TE}		10	pF
High Frequency Current Gain f = 100 MHz $I_C = 10mA$ $V_{CE} = 15V$	h_{fe}	2. 5		
Small Signal Current Gain f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{fe}	40 50	200 250	
Input Resistance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{ie}		6000 2000	ohms ohms
Output Conductance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{oe}		75 125	μmho μmho

(1) Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 1.0%

2N916 (SILICON)

2N916 JAN Available

CASE 22
(TO-18)
Collector
connected to case

NPN silicon annular transistor for high-frequency amplifier, oscillator and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	 1.2 6.9	 W mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	 .36 2.06	 W mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +300	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $I_E = 0$ $V_{CB} = 30V$	I_{CBO}		10	nAdc
Collector Cutoff Current @150° C $I_E = 0$ $V_{CB} = 30V$	I_{CBO}		10	µAdc
Collector Breakdown Voltage $I_C = 10\mu A$ $I_E = 0$	BV_{CBO}	45		Vdc
Collector to Emitter Sustaining Voltage (1) $I_C = 30mA$ $I_B = 0$	V_{CEO}	25		Vdc
Emitter Breakdown Voltage $I_C = 0$ $I_E = 10\ \mu A$	BV_{EBO}	5.0		Vdc
Base Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{BE(sat)}$		0.9	Vdc
Collector Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{CE(sat)}$		0.5	Vdc
DC Pulse Current Gain (1) $I_C = 10mA$ $V_{CE} = 1.0V$	h_{FE}	50	200	—
Output Capacitance $I_E = 0$ $V_{CB} = 5.0V$	C_{ob}		6.0	pF
Emitter Transition Capacitance $I_C = 0$ $V_{EB} = 0.5V$	C_{TE}		10	pF
High Frequency Current Gain f = 100 MHz $I_C = 10mA$ $V_{CE} = 15V$	h_{fe}	3.0		—
Small Signal Current Gain f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{fe}	40 50	200 250	
Input Resistance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{ie}		6000 2000	ohms ohms
Output Conductance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{oe}		75 125	µmho µmho

(1) **Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤1.0%**

2N918 (SILICON)

2N918 JAN, JTX AVAILABLE

NPN SILICON ANNULAR TRANSISTORS

. . . designed for use in VHF and UHF amplifier, mixer and oscillator applications.

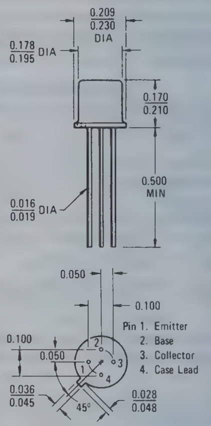
- High Current-Gain — Bandwidth Product —
  f_T = 600 MHz (Min) @ f = 100 MHz
- Low Output Capacitance —
  C_{ob} = 1.7 pF (Max) @ V_{CB} = 10 Vdc
- Collector-Emitter Sustaining Voltage —
  $V_{CEO(sus)}$ = 15 Vdc (Min) @ I_C = 3.0 mAdc
- JAN/JANTX Also Available

NPN SILICON AMPLIFIER TRANSISTORS

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current — Continuous	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 1.14	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	300 1.71	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data

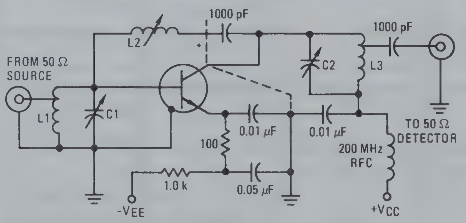


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.100
0.050
Pin 1. Emitter
2. Base
3. Collector
4. Case Lead
0.036
0.045
45°
0.028
0.048

CASE 20 (10)
TO-72 PACKAGE

To convert inches to millimeters multiply by 25.4.
All JEDEC TO-72 dimensions and notes apply.

FIGURE 1 — NEUTRALIZED 200 MHz POWER AMPLIFIER GAIN TEST CIRCUIT



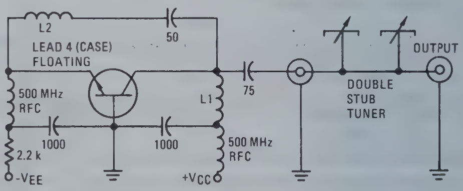
1000 pF
L2
*
1000 pF
FROM 50 Ω
SOURCE
C2
L3
L1
C1
0.01 µF
0.01 µF
TO 50 Ω
DETECTOR
100
200 MHz
RFC
1.0 k
0.05 µF
-V_{EE}
+V_{CC}

CIRCUIT COMPONENT INFORMATION:

C1: 3.0-12 pF
C2: 1.5-7.5 pF
L1: 3 1/2 turns #16 AWG 5/16" ID, 7/16" length, turns ratio -2 to 1
L2: 0.4-0.65 µH Miller #4303 (or equal)
L3: 8 turns #16 AWG 1/8" ID, 7/8" length, turns ratio — 8 to 1

*External interlead shield to isolate collector lead from emitter and base leads.

FIGURE 2 — 500 MHz OSCILLATOR TEST CIRCUIT



L2
50
LEAD 4 (CASE)
FLOATING
OUTPUT
500 MHz
RFC
L1
75
DOUBLE
STUB
TUNER
1000
1000
2.2 k
500 MHz
RFC
-V_{EE}
+V_{CC}

CIRCUIT COMPONENT INFORMATION:

L1: 2 turns #16 AWG, 3/8" OD, 1 1/4" length
L2: 9 turns #22 AWG, 3/16" OD, 1/2" length

Capacitance values are in pF.

Double Stub Tuner consists of the following commercially available components.

2 GR Type 874 TEE
1 GR Type 874-D20 Adjustable Stub
1 GR Type 874-LA Adjustable Line
1 GR Type 874-WN3 Short-Circuit Termination
(or equivalents)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 3.0 mAdc, I_B = 0)	$V_{CEO(sus)}$	15	–	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	30	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	3.0	–	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 – –	 .010 1.0	 μAdc μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	20	–	–
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	–	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	–	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (1) (I_C = 4.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	600	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz) (V_{CB} = 0, I_E = 0, f = 140 kHz)	C_{ob}	 – –	 1.7 3.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	–	2.0	pF
Noise Figure (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, R_G = 400 Ohms, f = 60 MHz)	NF	–	6.0	dB
FUNCTIONAL TEST				
Amplifier Power Gain (Figure 1) (V_{CB} = 12 Vdc, I_C = 6.0 mAdc, f = 200 MHz)	G_{pe}	15	–	dB
Power Output (Figure 2) (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	P_{out}	30	–	mW
Collector Efficiency (Figure 2) (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	η	25	–	%

*Indicates JEDEC Registered Data.

(1) f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N929, A (SILICON)
2N930, A

2N929 JAN AVAILABLE
2N930 JAN AVAILABLE

CASE 22
(TO-18)
Collector connected to case

NPN silicon annular transistors for low-level, low-noise amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N929 2N930	2N929A 2N930A	Unit
Collector-Emitter Voltage	V_{CEO}	45	60	Vdc
Collector-Base Voltage	V_{CB}	45	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	6.0	Vdc
Collector Current	I_C	30		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.5 3.33		W mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.8 12		Watt mW/°C
Operating Junction Temperature Range	T_J	-65to + 175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N929A, 2N930A	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	2N929, 2N930	BV_{EBO}	5.0	-	Vdc
	2N929A, 2N930A		6.0	-	
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)		I_{CEO}	-	2.0	nAdc
Collector Cutoff Current (V_{CE} = 45 Vdc, V_{BE} = 0)	2N929, 2N930	I_{CES}	-	10	nAdc
	2N929A, 2N930A		-	2.0	
(V_{CE} = 45 Vdc, V_{BE} = 0, T_A = 170°C)	2N929, 2N930		-	10	μAdc
	2N929A, 2N930A		-	2.0	
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)	2N929, 2N930	I_{CBO}	-	10	nAdc
	2N929A, 2N930A		-	2.0	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	2N929, 2N930	I_{EBO}	-	10	nAdc
	2N929A, 2N930A		-	2.0	

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)	2N929A	h_{FE}	25	-	-
	2N930A		60	-	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N929, 2N929A		40	120	
	2N930, 2N930A		100	300	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	2N929		10	-	
	2N929A		15	-	
	2N930		20	-	
	2N930A		30	-	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc)	2N929, 2N929A		60	-	
	2N930, 2N930A		150	-	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) [1]	2N929, 2N929A		-	350	
	2N930, 2N930A		-	600	
Collector-Emitter Saturation Voltage [1] (I_C = 10 mAdc, I_B = 0.5 mAdc)	2N929, 2N930	$V_{CE(sat)}$	-	1.0	Vdc
	2N929A, 2N930A		-	0.5	
Base-Emitter Saturation Voltage [1] (I_C = 10 mAdc, I_B = 0.5 mAdc)	2N929, 2N930 2N929A, 2N930A	$V_{BE(sat)}$	0.6	1.0	Vdc

SMALL-SIGNAL CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Current-Gain—Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)	2N929, 2N930	f_T	30	-	MHz
	2N929A, 2N930A		45	-	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	2N929, 2N930	C_{ob}	-	8.0	pF
	2N929A, 2N930A		-	6.0	
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{rb}	-	600	X 10^{-6}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N929, 2N929A	h_{fe}	60	350	-
	2N930, 2N930A		150	600	
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	1.0	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz)	2N929, 2N929A	NF	-	4.0	dB
	2N930, 2N930A		-	3.0	

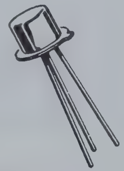
[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N956

For Specifications, See 2N718A Data.

2N960 (GERMANIUM)
2N961
2N962

2N962JAN AVAILABLE
2N964
2N964JAN AVAILABLE
2N965
2N966



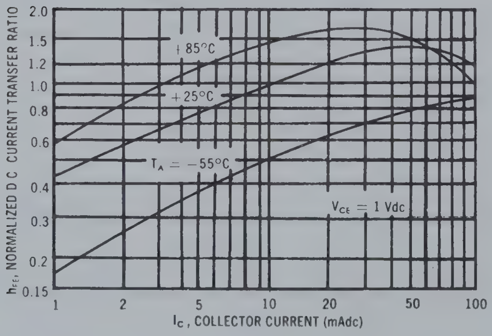
CASE 22
(TO-18)
Collector connected to case

PNP germanium epitaxial mesa transistors for high-speed switching applications.

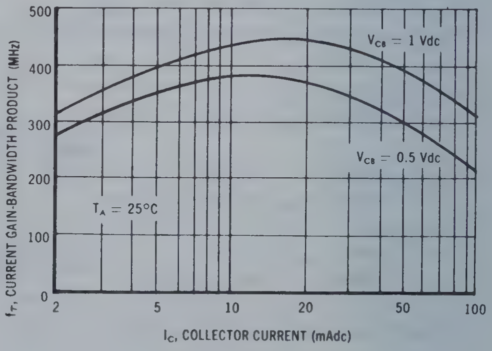
MAXIMUM RATINGS

Characteristic	Symbol	2N960 2N964	2N961 2N965	2N962 2N966	Unit
Collector-Emitter Voltage	V_{CE}	15	12	12	Vdc
Collector-Base Voltage	V_{CB}	15	12	12	Vdc
Emitter-Base Voltage	V_{EB}	2.5	2.0	1.25	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0			mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0			mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100			^oC

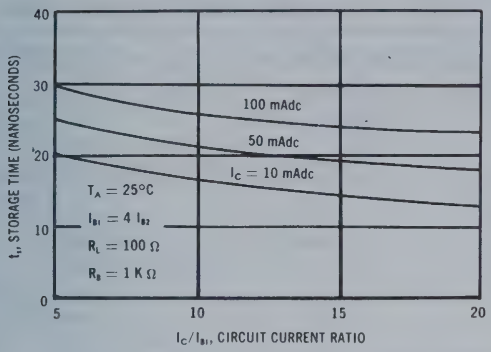
NORMALIZED D C CURRENT TRANSFER RATIO
versus COLLECTOR CURRENT



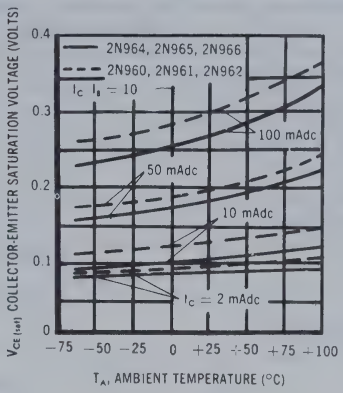
CURRENT GAIN-BANDWIDTH PRODUCT (f_T)
versus COLLECTOR CURRENT



STORAGE TIME versus CIRCUIT RATIO



COLLECTOR-EMITTER SATURATION VOLTAGE versus AMBIENT TEMPERATURE



ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

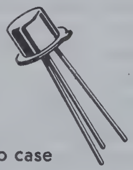
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N960, 2N964	BV_{CBO}	15	25	-	Vdc
	2N961, 2N962, 2N965, 2N966		12	20	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N960, 2N964	BV_{EBO}	2.5	-	-	Vdc
	2N961, 2N965		2.0	-	-	
	2N962, 2N966		1.25	-	-	
Collector-Latch-up Voltage V_{CC} = 11.5 Vdc		LV_{CEX}	11.5	-	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 15 Vdc)	2N960, 2N964	I_{CES}	-	-	100	μAdc
(V_{CE} = 12 Vdc)	2N961, 2N962, 2N965, 2N966		-	-	100	
Collector-Base Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	0.4	3.0	μAdc
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc)	2N960, 2N961, 2N962	h_{FE}	20	40	-	-
	2N964, 2N965, 2N966		40	70	-	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N960, 2N961, 2N962		20	55	-	
	2N964, 2N965, 2N966		40	90	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	2N960, 2N961, 2N962		20	50	-	
	2N964, 2N965, 2N966		40	85	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	2N964, 2N965, 2N966	$V_{CE(sat)}$	-	0.11	0.18	Vdc
	2N960, 2N961, 2N962		-	0.13	0.20	
(I_C = 50 mAdc, I_B = 5 mAdc)	2N964, 2N965, 2N966		-	0.18	0.35	
	2N960, 2N961, 2N962		-	0.20	0.40	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N964, 2N965, 2N966		-	0.27	0.60	
	2N960, 2N961, 2N962		-	0.30	0.70	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	All Types	$V_{BE(sat)}$	0.30	0.40	0.50	Vdc
(I_C = 50 mAdc, I_B = 5 mAdc)	All Types		0.40	0.55	0.75	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N960, 2N961, 2N964, 2N965		0.40	0.65	1.00	
	2N962, 2N966		0.40	0.75	1.25	
Current-Gain – Bandwidth Product (I_E = 20 mAdc, V_{CB} = 1.0 Vdc, f = 100 MHz)		f_T	300	460	-	MHz

2N960 SERIES (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	2.2	4.0	pF
Emitter Transition Capacitance (V_{EB} = 1 Vdc)	C_{Te}	-	2.0	3.5	pF
Turn-On Time All Types (I_C = 10 mAdc, I_{B1} = 5 mAdc, $V_{BE(off)}$ = 1.25 Vdc)	t_{on}	-	35	50	ns
(I_C = 100 mAdc, I_{B1} = 5 mAdc, $V_{BE(off)}$ = 1.25 Vdc)		-	30	50	
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 0.25 mAdc)	t_{off}				ns
2N960, 2N961, 2N964, 2N965		-	60	85	
2N962, 2N966		-	80	100	
(I_C = 100 mAdc, I_{B1} = 5 mAdc, I_{B2} = 1.25 mAdc)					
2N960, 2N961, 2N964, 2N965		-	50	85	
2N962, 2N966		-	60	100	
Rise Time Constant	τ_{RE}	-	0.6	-	ns
Hole Storage Factor	K'_s	-	16	-	ns
Fall Time Constant	τ_{FE}	-	0.5	-	ns
Total Control Charge	Q_T				pC
(I_C = 10 mAdc, I_B = 1 mAdc) 2N960, 2N961, 2N964, 2N965		-	50	80	
2N962, 2N966		-	60	90	
(I_C = 100 mAdc, I_B = 5 mAdc) 2N960, 2N961, 2N964, 2N965		-	80	125	
2N962, 2N966		-	100	150	

2N963 (GERMANIUM)
2N967



CASE 22
(TO-18)
Collector
connected to case

PNP germanium epitaxial mesa transistors for high-speed switching applications.

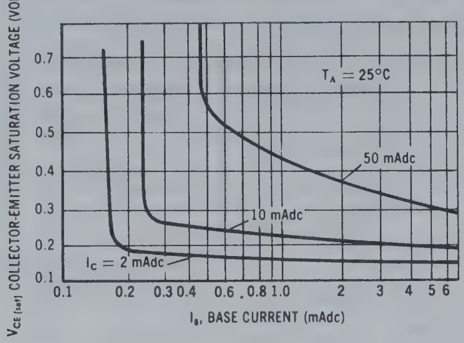
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	300 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	100	°C

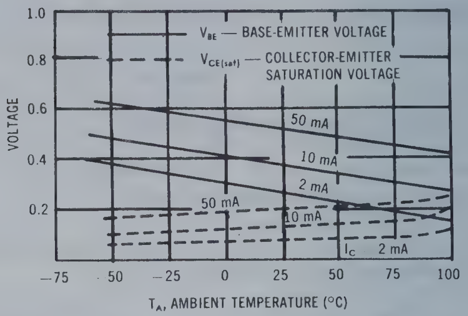
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	12	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.0	-	Vdc
Collector-Latch-up Voltage (V_{CC} = 10 Vdc)	LV_{CEX}	10	-	Vdc
Collector Cutoff Current (V_{CE} = 12 Vdc, V_{BE} = 0)	I_{CES}	-	100	μAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.3 Vdc, T_A = 55°C)	I_{CEX}	-	20	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	I_{CBO}	-	5.0	μAdc
Emitter Cutoff Current (V_{BE} = 5 Vdc, I_C = 0)	I_{EBO}	-	1.0	mAdc
Base Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.3 Vdc, T_A = 55°C)	I_{BL}	-	20	μAdc
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) 2N963 2N967	h_{FE}	20 40	- -	-
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc	$V_{CE(sat)}$	-	0.2	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.3	0.5	Vdc
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	5.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	4.0	pF
Turn-On Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, $V_{BE(off)}$ = 1.25 Vdc)	t_{on}	-	60	ns
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 1.25 mAdc)	t_{off}	-	120	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	Q_T	-	120	pC

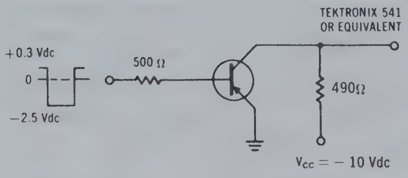
COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT



VOLTAGE versus TEMPERATURE CHARACTERISTICS

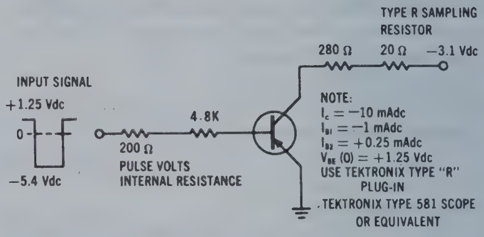


COLLECTOR LATCH-UP VOLTAGE TEST CIRCUIT



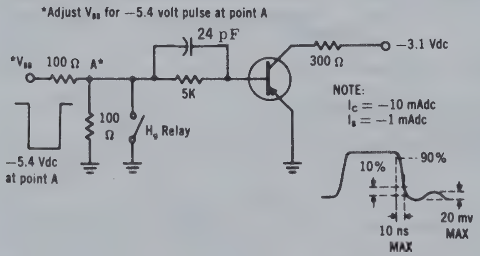
+0.3 Vdc
0
−2.5 Vdc
500 Ω
TEKTRONIX 541 OR EQUIVALENT
490Ω
$V_{CC} = -10$ Vdc

10-mA (I_C) SWITCHING TIME TEST CIRCUIT



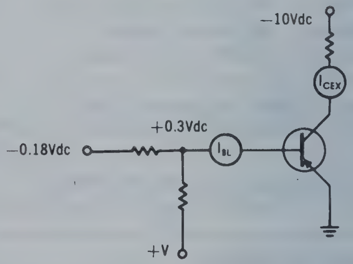
TYPE R SAMPLING RESISTOR
280 Ω
20 Ω
−3.1 Vdc
INPUT SIGNAL
+1.25 Vdc
0
−5.4 Vdc
4.8K
200 Ω
PULSE VOLTS INTERNAL RESISTANCE
NOTE:
$I_c = -10$ mAdc
$I_{B1} = -1$ mAdc
$I_{B2} = +0.25$ mAdc
$V_{BE}(0) = +1.25$ Vdc
USE TEKTRONIX TYPE "R" PLUG-IN
TEKTRONIX TYPE 581 SCOPE OR EQUIVALENT

BASE AND COLLECTOR CUTOFF CURRENT TEST CIRCUIT



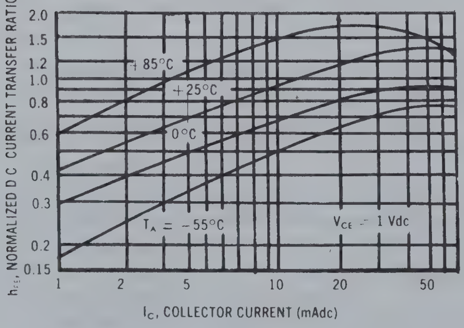
*Adjust V_{BB} for −5.4 volt pulse at point A
24 pF
$*V_{BB}$
100 Ω
A*
5K
300 Ω
−3.1 Vdc
100 Ω
H_g Relay
−5.4 Vdc at point A
NOTE:
$I_C = -10$ mAdc
$I_B = -1$ mAdc
10%
90%
10 ns MAX
20 mv MAX

10-mA (I_C) TOTAL CONTROL CHARGE TEST CIRCUIT

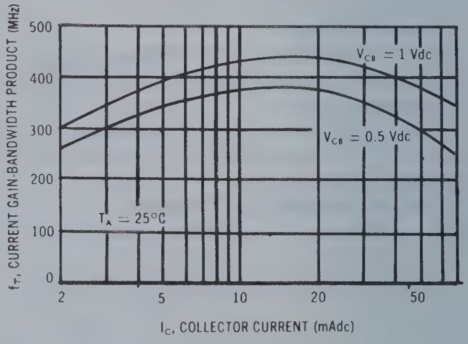


−10Vdc
I_{CEX}
+0.3Vdc
−0.18Vdc
I_{BL}
+V

NORMALIZED DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



CURRENT GAIN-BANDWIDTH PRODUCT (f_T) versus COLLECTOR CURRENT



2N964 (GERMANIUM)

For Specifications, See 2N960 Data.

2N964A (GERMANIUM)

PNP germanium epitaxial mesa transistor for high-speed switching applications.

CASE 22
(TO-18)
Collector Connected to Case

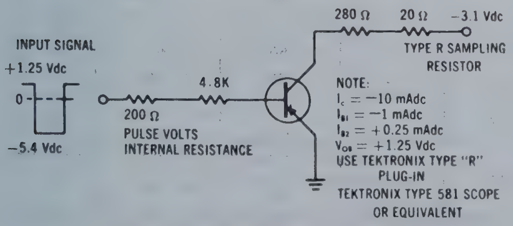
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	7.0	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.25	°C/mW
Thermal Resistance, Case to Ambient	θ_{CA}	0.5	°C/mW

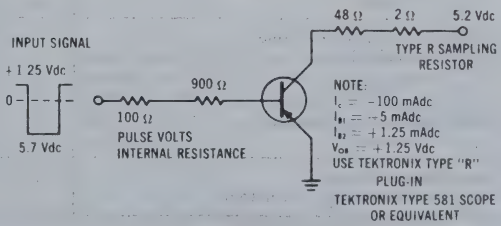
FIGURE 1


280 Ω
20 Ω
−3.1 Vdc
INPUT SIGNAL
+1.25 Vdc
0
−5.4 Vdc
4.8K
200 Ω
PULSE VOLTS
INTERNAL RESISTANCE
TYPE R SAMPLING
RESISTOR

NOTE:
$I_c = -10$ mAdc
$I_{B1} = -1$ mAdc
$I_{B2} = +0.25$ mAdc
$V_{OB} = +1.25$ Vdc
USE TEKTRONIX TYPE "R"
PLUG-IN
TEKTRONIX TYPE 581 SCOPE
OR EQUIVALENT

10-mA (I_C) SWITCHING TIME TEST CIRCUIT

FIGURE 2


48 Ω
2 Ω
5.2 Vdc
INPUT SIGNAL
+1.25 Vdc
0
5.7 Vdc
900 Ω
100 Ω
PULSE VOLTS
INTERNAL RESISTANCE
TYPE R SAMPLING
RESISTOR

NOTE:
$I_c = -100$ mAdc
$I_{B1} = -5$ mAdc
$I_{B2} = +1.25$ mAdc
$V_{OB} = +1.25$ Vdc
USE TEKTRONIX TYPE "R"
PLUG-IN
TEKTRONIX TYPE 581 SCOPE
OR EQUIVALENT

100-mA (I_C) SWITCHING TIME TEST CIRCUIT

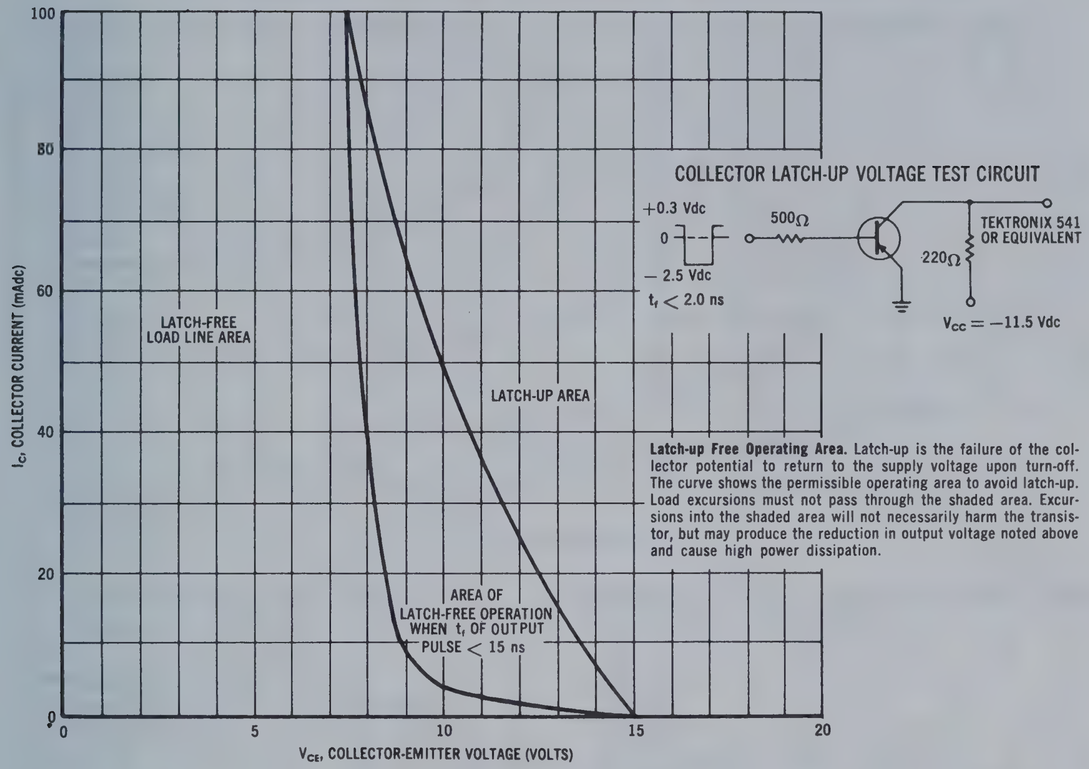
2N964A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig.	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	7.0	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	15	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	2.5	-	-	Vdc
Collector Latch-up Voltage	3	LV_{CEX}	11.5	-	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)		I_{CES}	-	-	100	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	0.4	3.0	μAdc
Base Leakage Current (V_{CE} = 6 Vdc, $V_{BE(off)}$ = 0.5 Vdc) (V_{CE} = 6 Vdc, $V_{BE(off)}$ = 0.5 Vdc, T_J = 85°C)	4	I_{BL}	- -	- 50	4.0 140	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) (I_C = 10 mAdc, V_{CE} = 0.3 Vdc, T_J = -55°C) (I_C = 50 mAdc, V_{CE} = 1 Vdc) (I_C = 100 mAdc, V_{CE} = 1 Vdc) (I_C = 100 mAdc, V_{CE} = 1 Vdc, T_J = 85°C)	8	h_{FE}	40 20 48 40 35	80 45 105 95 85	- - - - -	
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	5	$V_{CE(sat)}$	- - -	0.1 0.16 0.22	0.18 0.28 0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	6	$V_{BE(sat)}$	0.3 0.4 0.4	0.38 0.48 0.6	0.44 0.58 0.72	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 20 mAdc, V_{CB} = 1 Vdc, f = 100 MHz)		f_T	300	460	-	MHz
High-Frequency Current Gain (I_C = 20 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)		h_{fe}	3.0	4.6	-	-
Output Capacitance (V_{CB} = 1 Vdc, I_E = 0, f = 1 MHz) (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	11	C_{ob}	- -	2.7 2.2	5.0 4.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	11	C_{ib}	-	2.0	3.5	pF
Delay Time Plus Rise Time (I_C = 10 mAdc) (I_C = 100 mAdc)	 1 2	$t_d + t_r$	- -	35 30	50 50	ns
Storage Time Plus Fall Time (I_C = 10 mAdc) (I_C = 100 mAdc)	 1 2	$t_s + t_f$	- -	60 50	85 85	ns
Active Region Time Constant (I_C = 10 mAdc)	9	τ_A	-	0.6	1.5	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	10	Q_T	-	50	75	pC

2N964A LIMIT CURVES

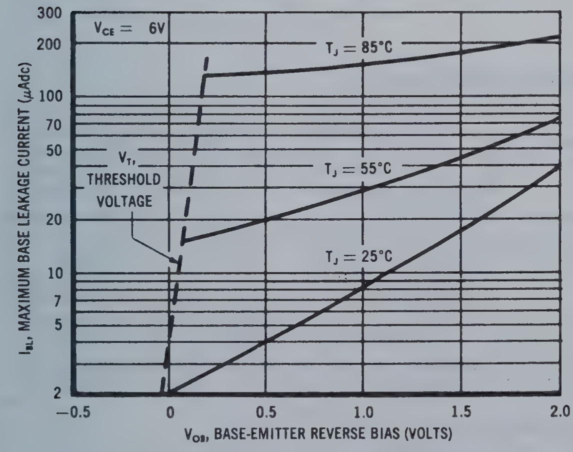
FIGURE 3—AREA OF PERMISSIBLE LOAD LOCI

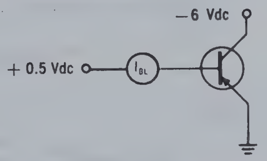


COLLECTOR LATCH-UP VOLTAGE TEST CIRCUIT

Latch-up Free Operating Area. Latch-up is the failure of the collector potential to return to the supply voltage upon turn-off. The curve shows the permissible operating area to avoid latch-up. Load excursions must not pass through the shaded area. Excursions into the shaded area will not necessarily harm the transistor, but may produce the reduction in output voltage noted above and cause high power dissipation.

FIGURE 4—COMMON EMITTER DC LEAKAGE CHARACTERISTICS





BASE LEAKAGE CURRENT TEST CIRCUIT

Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_c is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of conduction.)

NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

2N964A LIMIT CURVES

FIGURE 5—COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

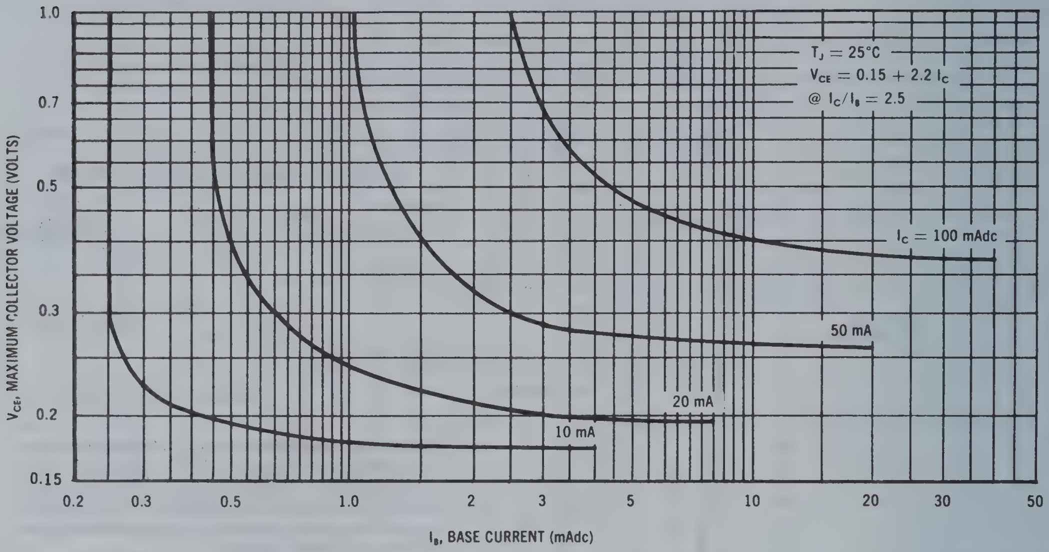


FIGURE 6—BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

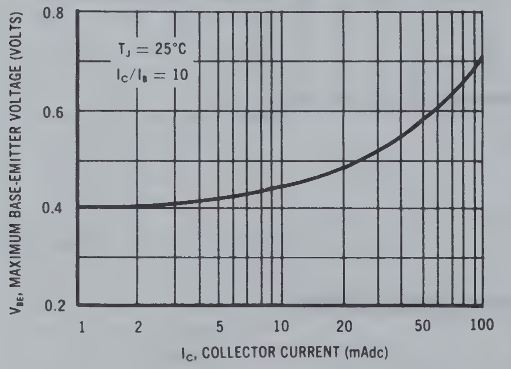


FIGURE 7—TEMPERATURE CO-EFFICIENTS

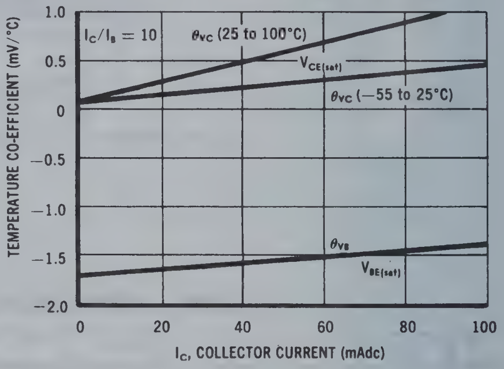
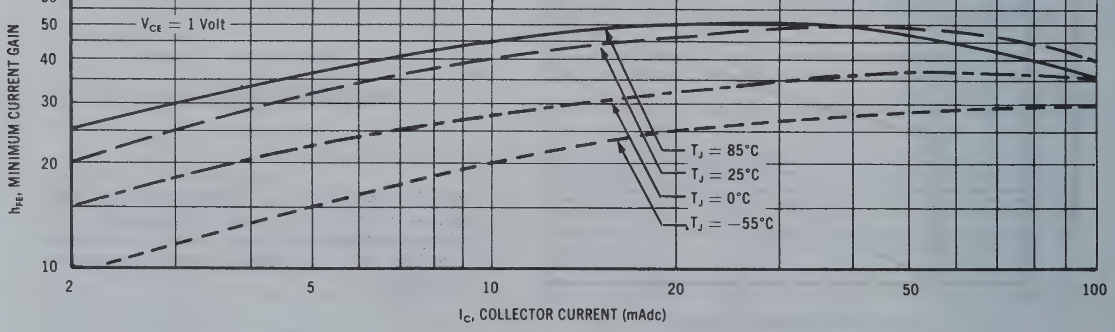


FIGURE 8—CURRENT GAIN CHARACTERISTICS

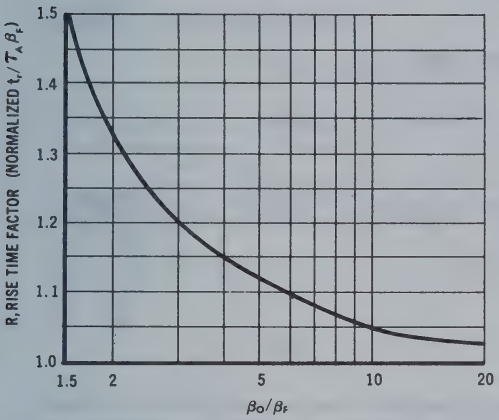


NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

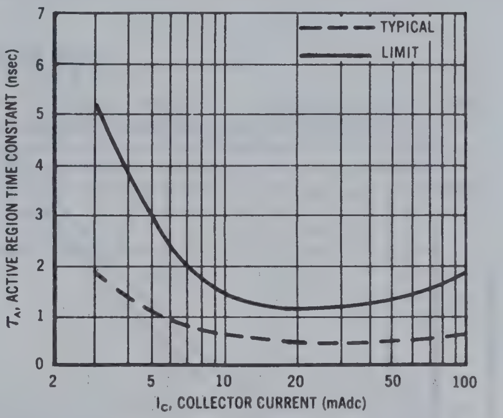
2N964A LIMIT CURVES

FIGURE 9—SWITCHING TIME CURVES FOR RESISTOR COUPLED CIRCUITS

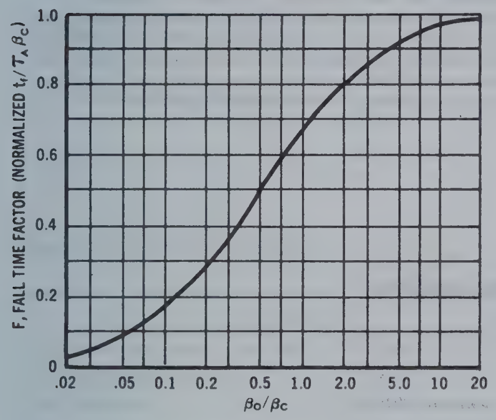
9a—RISE TIME FACTOR



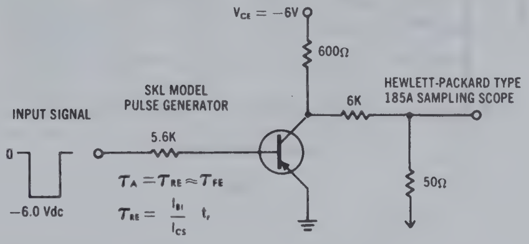
9b—ACTIVE REGION TIME CONSTANT



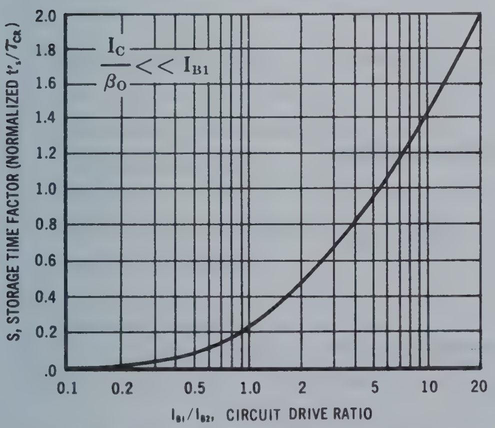
9c— FALL TIME FACTOR



ACTIVE REGION TIME CONSTANT TEST CIRCUIT


$V_{CE} = -6V$
600Ω
SKL MODEL
PULSE GENERATOR
INPUT SIGNAL
0
−6.0 Vdc
5.6K
6K
HEWLETT-PACKARD TYPE
185A SAMPLING SCOPE
50Ω
$\tau_A = \tau_{RE} \approx \tau_{FE}$
$\tau_{RE} = \frac{I_{B1}}{I_{CS}} t_r$

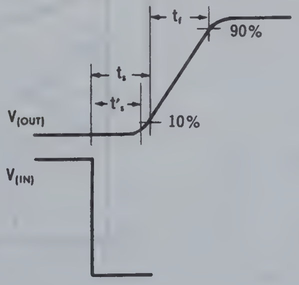
9d—STORAGE TIME



SWITCHING TIME EQUATIONS

RISE-TIME = $t_r = \tau_A \beta_F R$
FALL-TIME = $t_f = \tau_A \beta_C F$
STORAGE TIME = $t'_s = \tau_{CR} S$
t_r = 10 to 90% rise-time
t_f = 10 to 90% fall-time
$t_s = t'_s + \frac{1}{8} t_f$
τ_{CR} = the effective collector recovery time and is virtually uninfluenced by current levels. 20 ns typical and 60 ns maximum for this transistor.

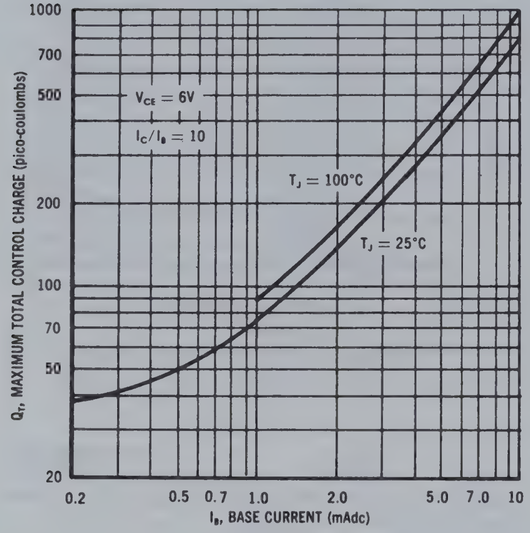
τ_A = active region time constant
$\tau_A = \tau_{RE} \approx \tau_{FE}$ (Figure 9b)
$\beta_O = h_{FE}$ at edge of saturation ($\beta_O \approx h_{FE}$ on Figure 8)
$\beta_F = I_C$ in saturation/I_{B1} (base "on" current)
$\beta_C = I_C$ in saturation/I_{B2} (base "off" current)
R see Figure 9a
F see Figure 9c
S see Figure 9d


t_f
90%
t_s
t'_s
$V_{(OUT)}$
10%
$V_{(IN)}$

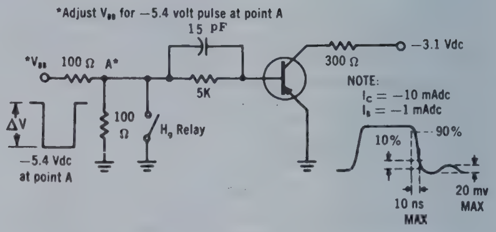
NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

2N964A LIMIT CURVES

FIGURE 10—TOTAL CONTROL CHARGE



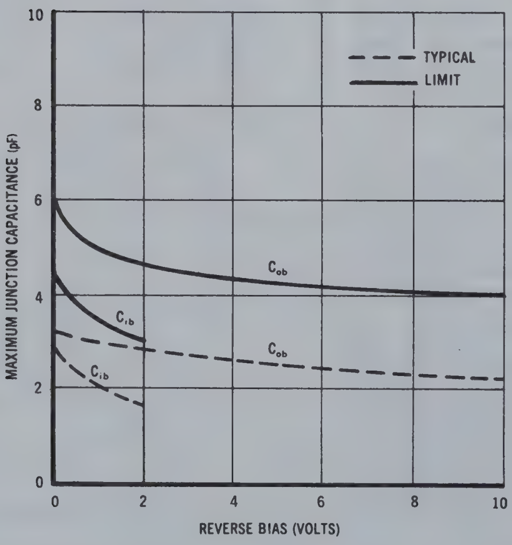
10a


*Adjust V_{BB} for −5.4 volt pulse at point A
15 pF
*V_{BB}
100 Ω
A*
5K
−3.1 Vdc
300 Ω
NOTE:
I_C = −10 mAdc
I_B = −1 mAdc
ΔV
−5.4 Vdc
at point A
100 Ω
H_g Relay
10%
90%
10 ns MAX
20 mv MAX

10b

Total Control Charge. When a transistor is held in a conductive state by a current, I_{B1}, a charge Q_S is developed in the active region. A charge Q_T of opposite polarity, equal in magnitude, can be stored on an external capacitor C to neutralize the internal charge and considerably reduce the turn-off time of the transistor. Figure 10b shows the test circuit and turn-off waveform. Given Q_T from Figure 10a, the external C for worst case turn-off in any circuit is: $C = Q_T/\Delta V$, where ΔV is defined in Figure 10b.

FIGURE 11— JUNCTION CAPACITANCE VARIATIONS



NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

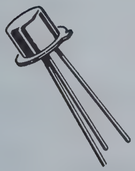
2N965 (GERMANIUM)
2N966

For Specifications, See 2N960 Data.

2N967 (GERMANIUM)

For Specifications, See 2N963 Data.

2N968 thru 2N975 (GERMANIUM)



CASE 22
(TO-18)

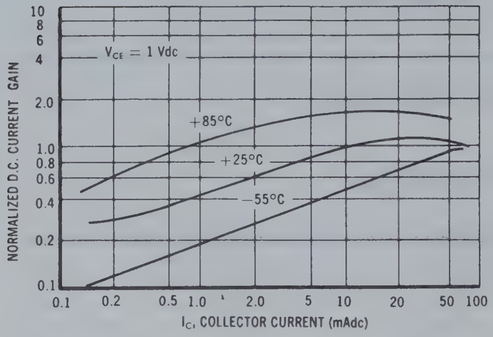
Collector connected to case

PNP germanium mesa transistors for high-speed switching applications.

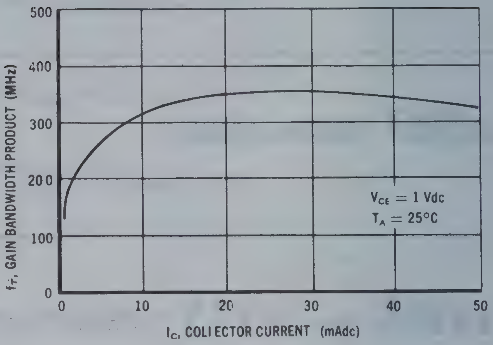
MAXIMUM RATINGS

Rating	Symbol	2N968 2N972	2N969 2N973	2N970 2N974	2N971 2N975	Unit
Collector-Emitter Voltage	V_{CES}	15	12	12	7.0	Vdc
Collector-Base Voltage	V_{CB}	15	12	12	7.0	Vdc
Emitter-Base Voltage	V_{EB}	2.5	2.0	1.25	1.25	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0				mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4.0				mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100				^oC

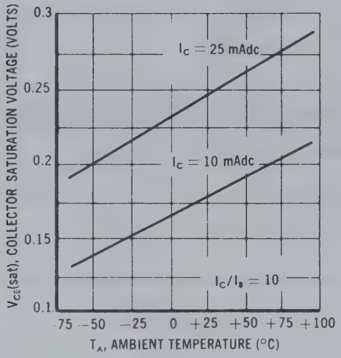
NORMALIZED D.C. CURRENT GAIN
versus COLLECTOR CURRENT



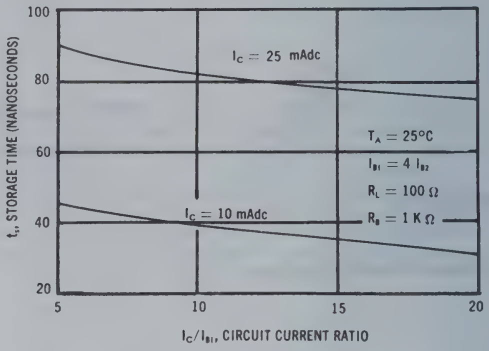
CURRENT GAIN-BANDWIDTH PRODUCT (f_T)
versus COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE versus AMBIENT TEMPERATURE



STORAGE TIME versus CIRCUIT CURRENT RATIO



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N968, 2N972	BV_{CBO}	15	25	-	Vdc
	2N969, 2N970, 2N973, 2N974		12	20	-	
	2N971, 2N975		7.0	15	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N968, 2N972	BV_{EBO}	2.5	-	-	Vdc
	2N969, 2N973		2.0	-	-	
	2N970, 2N974		1.25	-	-	
	2N971, 2N975		1.25	-	-	
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	2N968, 2N972	I_{CES}	-	-	100	μAdc
(V_{CE} = 12 Vdc, V_{BE} = 0)	2N969, 2N970, 2N973, 2N974		-	-	100	
(V_{CE} = 7 Vdc, V_{BE} = 0)	2N971, 2N975		-	-	100	
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	2N968, 2N969, 2N970,	I_{CBO}	-	-	3.0	μAdc
	2N972, 2N973, 2N974		-	-	3.0	
	2N971, 2N975		-	-	10	

ELECTRICAL CHARACTERISTICS (continued)

ON CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
DC Current Gain	h_{FE}				
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc) 2N968, 2N969, 2N970, 2N971		17	35	-	
2N972, 2N973, 2N974, 2N975		40	75	-	
(I_C = 25 mAdc, V_{CE} = 0.7 Vdc) 2N968, 2N969, 2N970, 2N971		20	40	-	
2N972, 2N973, 2N974, 2N975		40	85	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.19	0.25	
(I_C = 25 mAdc, I_B = 1.5 mAdc)		-	0.25	0.5	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc) 2N968, 2N969, 2N972, 2N973		0.30	0.39	0.55	
2N970, 2N971, 2N974, 2N975		0.30	0.43	0.65	
(I_C = 25 mAdc, I_B = 1.5 mAdc) 2N968, 2N969, 2N972, 2N973		-	0.45	0.80	
2N970, 2N971, 2N974, 2N975		-	0.60	1.0	

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Current-Gain — Bandwidth Product (I_E = 10 mAdc, V_{CB} = 1 Vdc, f = MHz)	f_T	250	320	-	MHz
Collector Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	4.0	9.0	pF
Emitter Transition Capacitance (V_{EB} = 1 Vdc, I_C = 0)	C_{Te}	-	3.5	-	pF
Turn-On Time ($V_{BE(off)}$ = 1.25 Vdc, I_C = 10 mAdc, I_{B1} = 1 mA)	t_{on}				ns
2N968, 2N969, 2N972, 2N973		-	50	75	
2N970, 2N971, 2N974, 2N975		-	65	100	
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 0.25 mAdc)	t_{off}				ns
2N968, 2N969		-	70	150	
2N972, 2N973		-	75	175	
2N970, 2N971, 2N974, 2N975		-	100	275	
Total Control Charge	Q_T				pC
(I_C = 10 mAdc, I_B = 1 mAdc) 2N968, 2N969, 2N972, 2N973		-	75	100	
2N970, 2N971, 2N974, 2N975		-	80	150	
(I_C = 25 mAdc, I_B = 1.5 mAdc) 2N968, 2N969, 2N972, 2N973		-	90	175	
2N970, 2N971, 2N974, 2N975		-	175	300	

2N978 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for general-purpose amplifier applications.

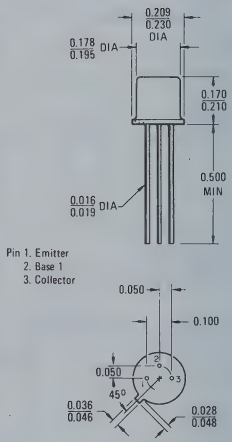
- Collector-Emitter Sustaining Voltage –
  $V_{CEO(sus)}$ = 20 Vdc (Min) @ I_C = 100 mAdc

PNP SILICON AMPLIFIER TRANSISTOR

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltate	V_{EB}	5.0	Vdc
Collector Current	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.33 2.64	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.25 10	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

Pin 1. Emitter
2. Base 1
3. Collector

Collector Connected to Case
CASE 22 (1)
(TO-18)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage(1) (I_C = 100 mAdc, I_B = 0)	$V_{CEO(sus)}$	20	–	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 mAdc, I_E = 0)	BV_{CBO}	30	–	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0 (V_{CB} = 10 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 – –	 5.0 200	μAdc
Emitter Cutoff Current (V_{EB} = 1.0 Vdc, I_C = 0)	I_{EBO}	–	200	μAdc
ON CHARACTERISTICS				
DC Current Gain(1) (I_C = 30 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc)	h_{FE}	 15 15	 – 60	–
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	–	1.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	–	1.5	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	–	45	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	h_{fe}	2.0	–	–

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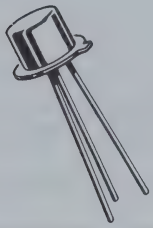
*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

2N985 (GERMANIUM)



CASE 22
(TO-18)

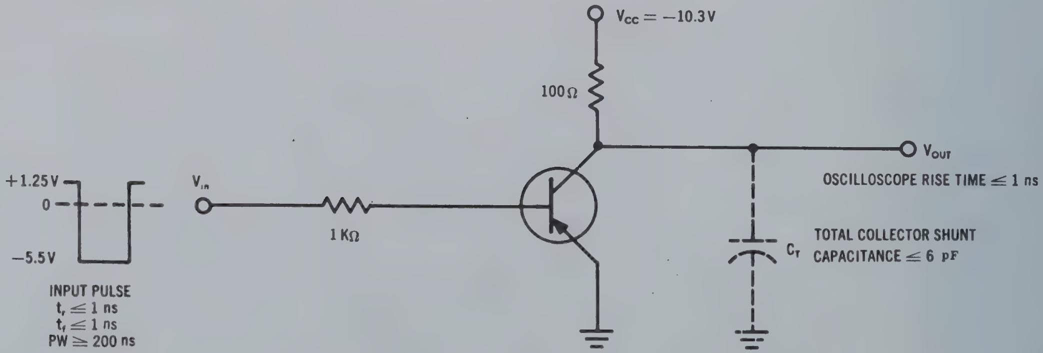
Collector connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	7.0	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	200	mAdc
Junction Temperature	T_J	100	^oC
Storage Temperature	T_{stg}	-65 to +100	^oC
Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	300 4.0	mW mW/^oC
Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	150 2.0	mW mW/^oC

SWITCHING TIME TEST CIRCUIT



$V_{CC} = -10.3 V$
100 Ω
V_{OUT}
OSCILLOSCOPE RISE TIME ≤ 1 ns
+1.25 V
0
−5.5 V
V_{in}
1 KΩ
C_T
TOTAL COLLECTOR SHUNT CAPACITANCE ≤ 6 pF
INPUT PULSE
$t_r \leq 1$ ns
$t_f \leq 1$ ns
PW ≥ 200 ns

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 5 mAdc, I_B = 0)	BV_{CEO}	7.0	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, R_{BE} = 0)	BV_{CES}	15	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	—	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	—	3.0	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	100	μAdc
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.25 Vdc) (I_C = 100 mAdc, V_{CE} = 0.5 Vdc)	h_{FE}	40 60	— —	—
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc) (I_C = 100 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$	— —	0.15 0.30	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc) (I_C = 100 mAdc, I_B = 5 mAdc)	V_{BE}	0.28 0.40	0.40 0.60	Vdc
Small Signal Current Gain (V_{CE} = 2 Vdc, I_C = 30 mAdc, f = 100 MHz)	$\|h_{fe}\|$	3.0	—	—
Collector Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	6.0	pF
Turn-on Time (I_C = 10 mAdc, I_{B1} = 5 mAdc, $V_{BE(0)}$ = 1.25 Vdc)	t_{on}	—	35	ns
Turn-off Time (I_C = 10 mAdc, I_{B1} = 5 mAdc, I_{B2} = 1.25 mA)	t_{off}	—	80	ns

2N995 (SILICON)

For Specifications, See 2N869 Data.

2N996 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for general-purpose amplifier applications.

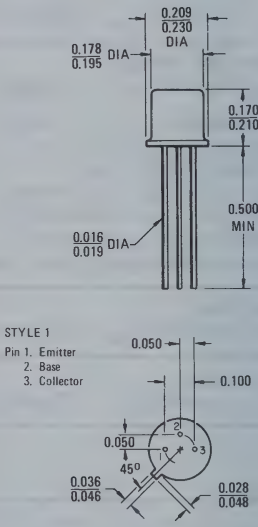
- Collector-Emitter Sustaining Voltage —
  $V_{CEO(sus)}$ = 12 Vdc (Min) @ I_C = 10 mAdc
- Collector-Base Breakdown Voltage —
  BV_{CBO} = 15 Vdc (Min) @ I_C = 10 μAdc
- Emitter-Base Breakdown Voltage —
  BV_{EBO} = 4.0 Vdc (Min) @ I_E = 10 μAdc

PNP SILICON TRANSISTOR

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.06	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.86	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
STYLE 1
Pin 1. Emitter
2. Base
3. Collector
0.050
0.100
0.050
45°
2
1
3
0.036
0.046
0.028
0.048

Collector Connected to Case
CASE 22(1)
(TO-18)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

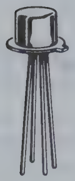
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage(1) (I_C = 10 mAdc, I_B = 0)	$V_{CEO(sus)}$	12	–	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0) (V_{CB} = 10 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	– –	0.005 15	μAdc μAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	–	10	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 20 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	35	–	–
Collector-Emitter Saturation Voltage (I_C = 60 mAdc, I_B = 2.0 mAdc)	$V_{CE(sat)}$	–	0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 20 mAdc, I_B = 2.0 mAdc)	$V_{BE(sat)}$	–	0.95	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	100	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz to 1.0 MHz)	C_{ob}	–	10	pF

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

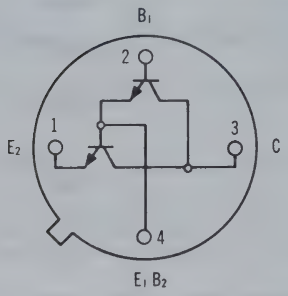
(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N998 (SILICON)



CASE 20(8)
(TO-72)

Darlington amplifier containing two NPN silicon annular transistors is designed for applications requiring very high-gain, low-noise, and high-input impedance.



MAXIMUM RATINGS

Rating	Symbol	2N998	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	0.5 2.86	Watt mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	1.8 10.3	Watts mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

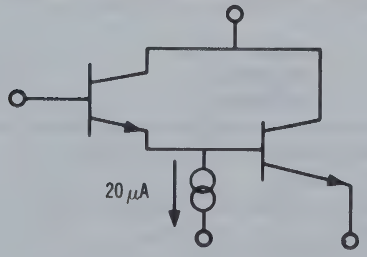
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage [1] (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	60	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	100	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	15	—	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0) (V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.01 15	μAdc
Emitter Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	I_{EBO}	—	0.01	μAdc
ON CHARACTERISTICS				
DC Current Gain [1] (I_C = 1 mAdc, V_{CE} = 5 Vdc) (I_C = 10 mAdc, V_{CE} = 5 Vdc) (I_C = 100 mAdc, V_{CE} = 5 Vdc) (I_C = 10 mAdc, V_{CE} = 5 Vdc, measured across each transistor within the device)	h_{FE}	800 1,600 2,000 25	— 8,000 — —	—
DYNAMIC CHARACTERISTICS				
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	30	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	50	pF
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	h_{fe}	1,000	—	—
Noise Figure** (I_C = 0.1 mAdc, V_{CE} = 10 Vdc, R_S = 5 kohms, f = 1 kHz, Bandwidth = 200 Hz)	NF**	—	6.0	dB

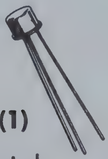
[1] Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1%

**Measured with constant current supply of 20 μAdc connected to the emitter of the input transistor. (See Figure 1)

FIGURE 1 — NOISE-FIGURE TEST CIRCUIT



2N1008, A, B (GERMANIUM)
2N1008B JAN AVAILABLE



CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for audio driver and medium speed switching applications.

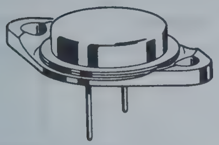
MAXIMUM RATINGS

Rating	Symbol	2N1008	2N1008A	2N1008B	Unit
Collector-Base Voltage	V_{CB}	20	40	60	Vdc
Collector-Emitter Voltage	V_{CEO}	20	40	60	Vdc
Emitter-Base Voltage	V_{EB}		15		Vdc
Collector Current	I_C		300		mAdc
Base Current	I_B		30		mAdc
Collector Dissipation $T_A = 25^oC$ derate $T_C = 25^oC$ derate	P_D		200 2.78 300 4.0		mW mW/^oC mW mW/^oC
Junction and Storage Temperature Range	T_J, T_{stg}		-65 to +100		^oC

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	UNIT
Collector Leakage Current	I_{CBO}				μAdc
(V_{CB} = 10 Vdc) 2N1008		---	5.0	10	
(V_{CB} = 10 Vdc, $T_A = 85^oC$) 2N1008		---	---	500	
(V_{CB} = 25 Vdc) 2N1008A		---	5.0	10	
(V_{CB} = 25 Vdc, $T_A = 85^oC$) 2N1008A		---	---	500	
(V_{CB} = 45 Vdc) 2N1008B		---	7.0	15	
(V_{CB} = 45 Vdc, $T_A = 85^oC$) 2N1008B		---	---	750	
Emitter Leakage Current	I_{EBO}				μAdc
(V_{EB} = 10 Vdc) 2N1008		---	5.0	10	
2N1008A		---	---	10	
2N1008B		---	---	10	
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, R_{BE} = 10 K)	BV_{CER}				Vdc
2N1008		15	---	---	
2N1008A		35	---	---	
2N1008B		55	---	---	
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc)	V_{CE} (sat)	---	---	0.25	Vdc
Small Signal Current Gain (I_C = -10 mAdc, V_{CE} = 5.0 Vdc, f = 1 kHz)	h_{fe}	40	---	150	---
Input Resistance (V_{CB} = 6 V, I_E = 1 mA)	h_{ie}	200	---	1000	ohms

2N1011 (GERMANIUM)



CASE 11
(TO-3)

PNP germanium power transistor for general purpose power amplifier and switching applications in military and industrial equipment. Operating temperature range and power dissipation exceed military specifications.

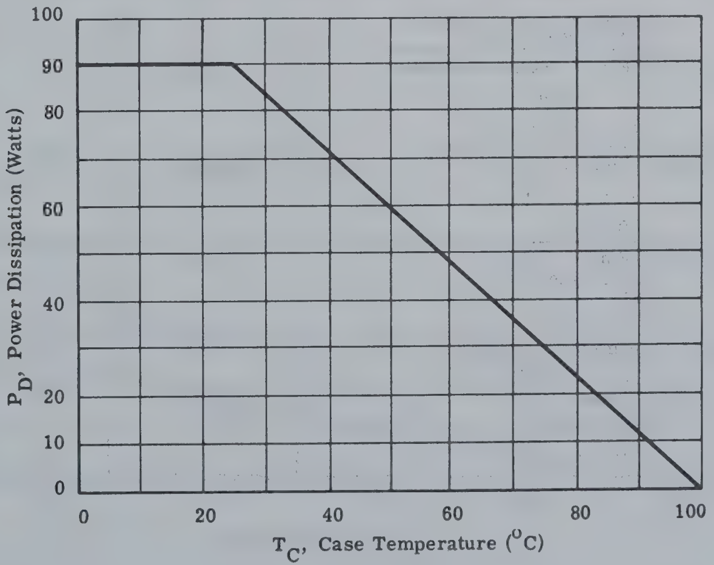
MAXIMUM RATINGS

Rating	Symbol	2N1011	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage	V_{CES}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Collector Current	I_C	5.0	Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	90 1.2	Watts $W/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^oC/W$

POWER-TEMPERATURE DERATING CURVE

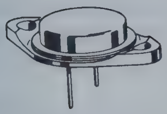


2N1011 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted).

Characteristic	Symbol	Minimum	Maximum	Unit
DC Current Transfer Ratio V_{CE} = 2 V I_C = 1.0 Adc	h_{FE}	—	150	—
DC Current Transfer Ratio V_{CE} = 2 V I_C = 3.0 Adc	h_{FE}	30	75	—
Small-Signal Current Transfer Ratio Cutoff Frequency V_{CE} = 2 Vdc I_C = 3 Amp	$f_{\alpha e}$	5.0	—	kHz
Emitter-Base Cutoff Current V_{EB} = 40 Vdc I_C = 0	I_{EBO}	—	3.0	mAdc
Collector-Base Cutoff Current V_{CB} = 2 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector-Base Cutoff Current V_{CB} = 80 Vdc I_E = 0	I_{CBO}	—	15.0	mAdc
Base Current V_{CE} = 2 Vdc I_C = 1 Adc	I_B	6.7	—	mAdc
Base Current V_{CE} = 2 Vdc I_C = 3 Adc	I_B	40	100	mAdc
Emitter-Base Voltage V_{CE} = 2 Vdc I_C = 3 Adc	V_{EB}	—	2.0	Vdc
Floating Potential V_{CB} = 50 Vdc (Voltmeter input resistance = 10 Megohm min)	V_{fl}	—	1.0	Vdc
Collector-Emitter Saturation Voltage I_C = 3 Adc I_B = 200 mAdc	$V_{CE(SAT)}$	—	1.5	Vdc
Collector-Emitter Voltage I_C = 300 mAdc I_B = 0	BV_{CEO}	40	—	Vdc
Collector-Emitter Voltage I_C = 300 mAdc V_{EB} = 0	BV_{CES}	80	—	Vdc
High-Temperature Operation T_C = +90°C min Collector Cutoff Current V_{CB} = 30 Vdc I_E = 0	I_{CBO}	—	20	mAdc

2N1021 (GERMANIUM)
2N1022



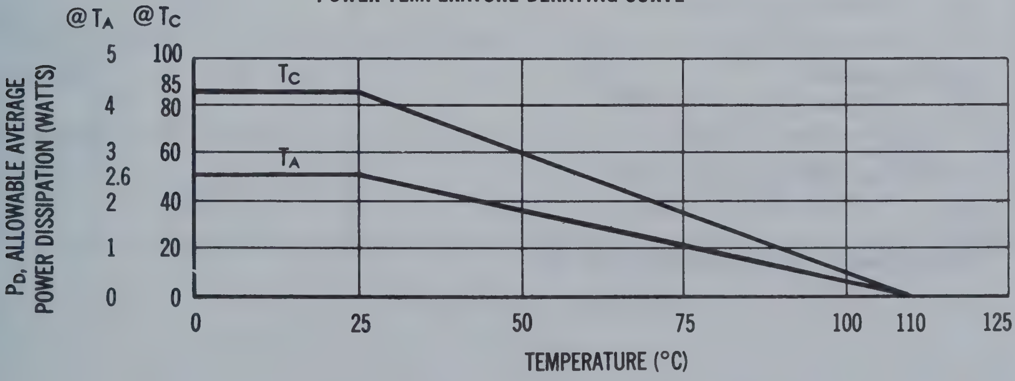
CASE 11
(TO-3)

PNP germanium power transistors for industrial and general purpose power amplifier and switching applications.

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	2N1021	2N1022	Unit
Collector-Base Voltage	V_{CB}	100	120	Volts
Collector-Emitter Voltage	V_{CEX}	100	120	Volts
Collector-Emitter Voltage	V_{CEO}	50		Volts
Emitter-Base Voltage	V_{EB}	30		Volts
Collector Current	I_C	5.0		Amp
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +110		°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	85 1.0		Watts W/°C

POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 50 Vdc)	2N1021		—	0.5	
(V_{CB} = 60 Vdc)	2N1022		—	0.5	
(V_{CB} = 100 Vdc)	2N1021		—	2.0	
(V_{CB} = 120 Vdc)	2N1022		—	2.0	
(V_{CB} = 50 Vdc, T_C = +55°C)	2N1021		—	8.0	
(V_{CB} = 60 Vdc, T_C = +55°C)	2N1022		—	8.0	
Collector-Emitter Breakdown Voltage* (I_C = 200 mAdc)		BV_{CEO}*	50	—	Vdc
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 10 Vdc)			—	0.5	
(V_{EB} = 30 Vdc)			—	2.0	
Base-Emitter Voltage (V_{CE} = -1.5 Vdc, I_C = 1.0 Adc)		V_{BE}	—	3.0	Vdc
Collector-Emitter Saturation Voltage (I_C = 5 Adc, I_B = 500 mAdc)		$V_{CE(sat)}$	—	0.5	Vdc
DC Current Gain		h_{FE}			—
(I_C = 1 Adc, V_{CE} = 1.5 Vdc)			40	—	
(I_C = 3 Adc, V_{CE} = 1.5 Vdc)			35	—	
(I_C = 5 Adc, V_{CE} = 1.5 Vdc)			30	90	
(I_C = 7 Adc, V_{CE} = 1.5 Vdc)			22	—	
Input Impedance (I_C = 1.0 Adc, V_{CE} = 1.5 Vdc)		h_{ie}	—	28	ohms
Current Gain-Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 2 Vdc)		f_T	200	—	kHz

*Sweep Test: 1/2 sine wave, 60 Hz .

2N1038 thru 2N1041 (GERMANIUM)
2N2552 thru 2N2559

PNP GERMANIUM MEDIUM POWER TRANSISTORS

. . . designed for relay drivers, pulse amplifiers, audio amplifiers and high-current switching applications.

- High Current Capability – I_C = 3.0 Amperes
- Guaranteed Excellent Collector-Emitter Sustaining Voltage
- 20-Watt Power Dissipation at 25°C Case Temperature
- 100°C Maximum Junction Temperature

PNP GERMANIUM POWER TRANSISTORS

40–100 VOLTS
20 WATTS

CASE 180

CASE 183

CASE 184

*MAXIMUM RATINGS

Rating	Symbol	2N1038 2N2552 2N2556	2N1039 2N2553 2N2557	2N1040 2N2554 2N2558	2N1041 2N2555 2N2559	Unit
Collector-Emitter Voltage	V_{CEO}	30	40	50	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	← 20 →				Vdc
Collector Current – Continuous	I_C	← 3.0 →				Adc
Base Current – Continuous	I_B	← 1.0 →				Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	← 450 → ← 6.0 →				mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C (Note 1)	P_D	← 20 → ← 0.267 →				Watts W/°C
**Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +100 →				°C

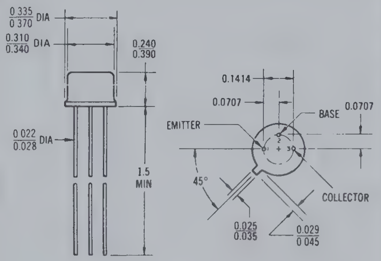
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	3.75	°C/W

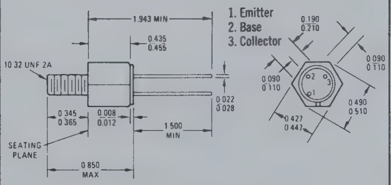
*Indicates JEDEC Registered Data.

Note 1: Case Temperature shall be measured 0.100 ± 0.010 inches above the seating plane.

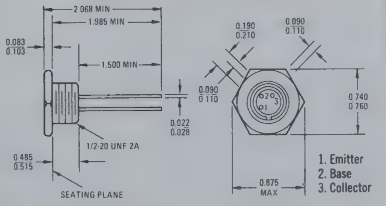
**Motorola guarantees this data in addition to the JEDEC Registered Data shown.


0.335 / 0.370 DIA
0.310 / 0.340 DIA
0.240 / 0.390
0.022 / 0.028 DIA
1.5 MIN
0.1414
0.0707
BASE
0.0707
EMITTER
2
1
3
45°
COLLECTOR
0.025 / 0.035
0.029 / 0.045

2N1038–2N1041 CASE 180


1.943 MIN
0.435 / 0.455
10 32 UNF 2A
1. Emitter
2. Base
3. Collector
0.190 / 0.210
0.090 / 0.110
0.090 / 0.110
0.022 / 0.028
0.345 / 0.365
0.008 / 0.012
1.500 MIN
0.490 / 0.510
0.427 / 0.447
SEATING PLANE
0.850 MAX

2N2552–2N2555 CASE 183


2.068 MIN
1.985 MIN
0.083 / 0.103
1.500 MIN
0.190 / 0.210
0.090 / 0.110
0.090 / 0.110
0.740 / 0.760
0.022 / 0.028
1/2-20 UNF 2A
0.485 / 0.515
SEATING PLANE
0.875 MAX
1. Emitter
2. Base
3. Collector

2N2556–2N2559 CASE 184
Collector Connected to Case
(All Types)

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N1038, 2N2552, 2N2556		30	-	
	2N1039, 2N2553, 2N2557		40	-	
	2N1040, 2N2554, 2N2558		50	-	
	2N1041, 2N2555, 2N2559		60	-	
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 15 Vdc, I_B = 0)	2N1038, 2N2552, 2N2556		-	25	
(V_{CE} = 20 Vdc, I_B = 0)	2N1039, 2N2553, 2N2557		-	20	
(V_{CE} = 25 Vdc, I_B = 0)	2N1040, 2N2554, 2N2558		-	20	
(V_{CE} = 30 Vdc, I_B = 0)	2N1041, 2N2555, 2N2559		-	20	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1038, 2N2552, 2N2556		-	0.65	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1039, 2N2553, 2N2557		-	0.65	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1040, 2N2554, 2N2558		-	0.65	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1041, 2N2555, 2N2559		-	0.65	
(V_{CE} = 20 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1038, 2N2552, 2N2556		-	5.0	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1039, 2N2553, 2N2557		-	5.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1040, 2N2554, 2N2558		-	5.0	
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1041, 2N2555, 2N2559		-	5.0	
Collector Cutoff Current		I_{CBO}			µAdc
(V_{CB} = 20 Vdc, I_E = 0)	2N1038, 2N2552, 2N2556		-	125	
(V_{CB} = 30 Vdc, I_E = 0)	2N1039, 2N2553, 2N2557		-	125	
(V_{CB} = 40 Vdc, I_E = 0)	2N1040, 2N2554, 2N2558		-	125	
(V_{CB} = 50 Vdc, I_E = 0)	2N1041, 2N2555, 2N2559		-	125	
**(V_{CB} = 40 Vdc, I_E = 0)	2N1038, 2N2552, 2N2556		-	750	
**(V_{CB} = 60 Vdc, I_E = 0)	2N1039, 2N2553, 2N2557		-	750	
**(V_{CB} = 80 Vdc, I_E = 0)	2N1040, 2N2554, 2N2558		-	750	
**(V_{CB} = 100 Vdc, I_E = 0)	2N1041, 2N2555, 2N2559		-	750	
Emitter Cutoff Current		I_{EBO}			µAdc
(V_{BE} = 20 Vdc, I_C = 0)			-	650	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 50 mAdc, V_{CE} = 0.5 Vdc)			33	200	
(I_C = 1.0 Adc, V_{CE} = 0.5 Vdc)			20	60	
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 100 mAdc)		$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter Input Voltage (I_C = 1.0 Adc, V_{CE} = 0.5 Vdc)		V_{BE}	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 1.0 kHz)		h_{fe}	18	72	-
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 112.5 kHz)		$\|h_{fe}\|$	2.0	-	-

*Indicates JEDEC Registered Data.

**Motorola Guarantees this data in addition to the JEDEC Registered Data Shown.

2N1042 thru 2N1045 (GERMANIUM)
2N2560 thru 2N2567

PNP GERMANIUM MEDIUM POWER TRANSISTORS

. . . designed for relay drivers, pulse amplifiers, audio amplifiers and high-current switching applications.

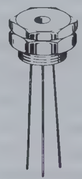
- High Current Capability – I_C = 3.5 Amperes
- Guaranteed Excellent Collector-Emitter Sustaining Voltage
- 20-Watt Power Dissipation at 25°C Case Temperature
- 100°C Maximum Junction Temperature

PNP GERMANIUM POWER TRANSISTORS

40–100 VOLTS
20 WATTS

CASE 180

CASE 183


CASE 184

*MAXIMUM RATINGS

Rating	Symbol	2N1042 2N2560 2N2564	2N1043 2N2561 2N2565	2N1044 2N2562 2N2566	2N1045 2N2563 2N2567	Unit
Collector-Emitter Voltage	V_{CEO}	30	40	50	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	20				Vdc
Collector Current – Continuous	I_C	3.5				Adc
Base Current – Continuous	I_B	1.0				Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	450 6.0				mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C (Note 1)	P_D	20 0.267				Watts W/°C
**Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100				°C

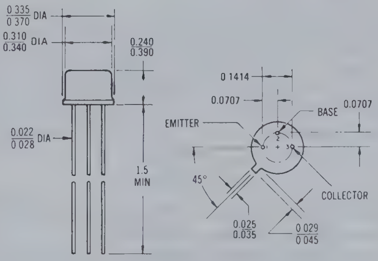
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	3.75	°C/W

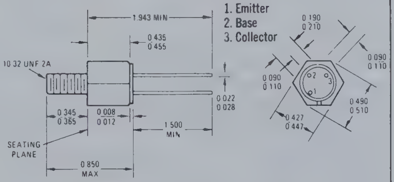
*Indicates JEDEC Registered Data.

Note 1: Case Temperature shall be measured 0.100 ± 0.010 inches above the seating plane.

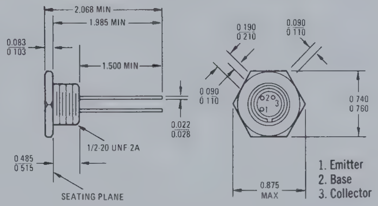
**Motorola guarantees this data in addition to the JEDEC Registered Data shown.


0.335 / 0.370 DIA
0.310 / 0.340 DIA
0.240 / 0.390
0.022 / 0.028 DIA
1.5 MIN
0 1414
0.0707
0.0707
EMITTER
BASE
COLLECTOR
45°
0.025 / 0.035
0.029 / 0.045

2N2564 – 2N2567 CASE 180


1.943 MIN
0.435 / 0.455
10 32 UNF 2A
0.345 / 0.365
0.008 / 0.012
1.500 MIN
0.022 / 0.028
SEATING PLANE
0.850 MAX
1. Emitter
2. Base
3. Collector
0.190 / 0.210
0.090 / 0.110
0.090 / 0.110
0.490 / 0.510
0.427 / 0.447

2N2560 – 2N2563 CASE 183


2.068 MIN
1.985 MIN
0.083 / 0.103
1.500 MIN
0.022 / 0.028
1/2-20 UNF 2A
0.485 / 0.515
SEATING PLANE
0.190 / 0.210
0.090 / 0.110
0.090 / 0.110
0.740 / 0.760
0.875 MAX
1. Emitter
2. Base
3. Collector

2N1042 – 2N1045 CASE 184
Collector Connected to Case

(All Types)

2N1042 thru 2N1045/2N2560 thru 2N2567 (continued)

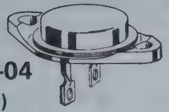
*ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N1042,2N2560,2N2564		30	–	
	2N1043,2N2561,2N2565		40	–	
	2N1044,2N2562,2N2566		50	–	
	2N1045,2N2563,2N2567		60	–	
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 15 Vdc, I_B = 0)	2N1042,2N2560,2N2564		–	25	
(V_{CE} = 20 Vdc, I_B = 0)	2N1043,2N2561,2N2565		–	20	
(V_{CE} = 25 Vdc, I_B = 0)	2N1044,2N2562,2N2566		–	20	
(V_{CE} = 30 Vdc, I_B = 0)	2N1045,2N2563,2N2567		–	20	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1042,2N2560,2N2564		–	0.65	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1043,2N2561,2N2565		–	0.65	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1044,2N2562,2N2566		–	0.65	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1045,2N2563,2N2567		–	0.65	
(V_{CE} = 20 Vdc, $V_{BE(off)}$ = 0.2 Vdc, $T_C = 85^oC$)	2N1042,2N2560,2N2564		–	5.0	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 0.2 Vdc, $T_C = 85^oC$)	2N1043,2N2561,2N2565		–	5.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc, $T_C = 85^oC$)	2N1044,2N2562,2N2566		–	5.0	
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.2 Vdc, $T_C = 85^oC$)	2N1045,2N2563,2N2567		–	5.0	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 20 Vdc, I_E = 0)	2N1042,2N2560,2N2564		–	125	
(V_{CB} = 30 Vdc, I_E = 0)	2N1043,2N2561,2N2565		–	125	
(V_{CB} = 40 Vdc, I_E = 0)	2N1044,2N2562,2N2566		–	125	
(V_{CB} = 50 Vdc, I_E = 0)	2N1045,2N2563,2N2567		–	125	
**(V_{CB} = 40 Vdc, I_E = 0)	2N1042,2N2560,2N2564		–	750	
**(V_{CB} = 60 Vdc, I_E = 0)	2N1043,2N2561,2N2565		–	750	
**(V_{CB} = 80 Vdc, I_E = 0)	2N1044,2N2562,2N2566		–	750	
**(V_{CB} = 100 Vdc, I_E = 0)	2N1045,2N2563,2N2567		–	750	
Emitter Cutoff Current (V_{BE} = 20 Vdc, I_C = 0)		I_{EBO}	–	650	μAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 50 mAdc, V_{CE} = 0.5 Vdc)			50	–	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)			–	150	
(I_C = 3.0 Adc, V_{CE} = 1.0 Vdc)			20	60	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 1.0 Adc, I_B = 100 mAdc)			–	0.25	
(I_C = 3.0 Adc, I_B = 300 mAdc)			–	0.75	
Base-Emitter Input Voltage (I_C = 3.0 Adc, V_{CE} = 1.0 Vdc)		V_{BE}	–	1.5	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 1.0 kHz)		h_{fe}	25	100	–
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 125 kHz)		$\|h_{fe}\|$	2.0	–	–

*Indicates JEDEC Registered Data.

**Motorola Guarantees this data in addition to the JEDEC Registered Data Shown.

2N1073, A, B (GERMANIUM)



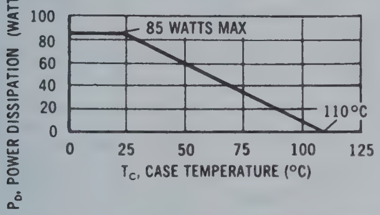
CASE 4-04
(TO-41)

PNP germanium power transistors for high-voltage power switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N1073	2N1073A	2N1073B	Unit
Collector-Emitter Voltage	V_{CER}	40	80	120	Vdc
Collector-Base Voltage	V_{CB}	40	80	120	Vdc
Emitter-Base Voltage	V_{EB}	1.5	1.5	1.5	Vdc
Collector Current (Cont)	I_C	10	10	10	Amp
Base Current (Cont)	I_B		5.0		Amp
Emitter Reverse Current (Surge 60 cps Recurrent)	I_E		1.5		Amp
Storage and Operating Temperature	T_{stg} T_J		-65 to +110		^oC
Collector Dissipation (25^oC Mtg. Case Temp.)	P_D		85		Watts

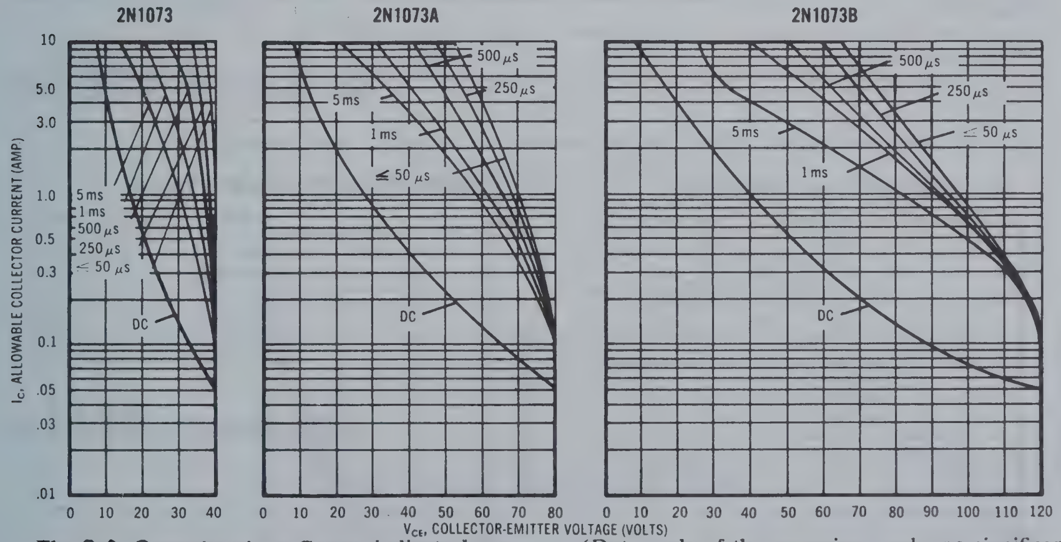
POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 85 watts at a case temperature of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that:

$$\text{Allowable } P_D = \frac{110° - T_C}{1.0} \text{ Watts}$$

SAFE OPERATING AREAS — PULSE CONDITIONS



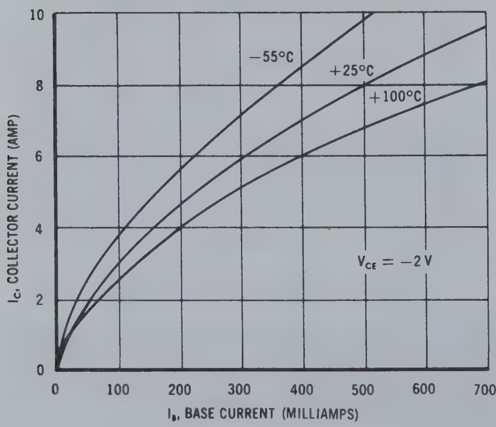
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

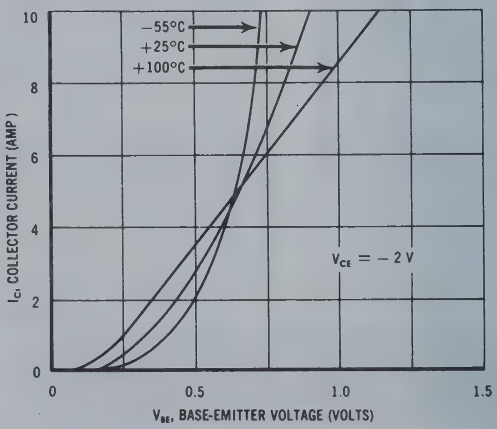
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 25 Vdc, I_E = 0)	2N1073		-	-	1.0	
(V_{CB} = 25 Vdc, I_E = 0, T_C = 85°C)	2N1073		-	-	15	
(V_{CB} = 40 Vdc, I_E = 0)	2N1073		-	-	20	
(V_{CB} = 60 Vdc, I_E = 0)	2N1073A		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0, T_C = 85°C)	2N1073A		-	-	15	
(V_{CB} = 80 Vdc, I_E = 0)	2N1073A		-	-	20	
(V_{CB} = 100 Vdc, I_E = 0)	2N1073B		-	-	2.0	
(V_{CB} = 100 Vdc, I_E = 0, T_C = 85°C)	2N1073B		-	-	20	
(V_{CB} = 120 Vdc, I_E = 0)	2N1073B		-	-	20	
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	0.3	
Emitter-Base Leakage Current (V_{EB} = 0.75 Vdc)		I_{EBO}	-	-	50	mAdc
Emitter Floating Potential		V_{EBF}				Vdc
(V_{CE} = 40 Vdc)	2N1073		-	-	1.0	
(V_{CE} = 80 Vdc)	2N1073A		-	-	1.0	
(V_{CE} = 120 Vdc)	2N1073B		-	-	1.0	
Collector-Emitter Breakdown Voltage* (I_C = 50 mAdc, R_{BE} = 100Ω)	2N1073	BV_{CER}*	40	-	-	Vdc
	2N1073A		80	-	-	
	2N1073B		120	-	-	
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	-	60	-
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 30 kHz)		h_{fe}	-	15	-	-
Base Input Voltage (V_{CE} = 2.0 Vdc, I_C = 5.0 Adc)		V_{BE}	-	-	1.0	Vdc
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{CE(sat)}$	-	0.5	1.0	Vdc
Rise Time		t_r	-	5.5	-	μs
Storage Time		t_s	-	1.2	-	μs
Fall Time		t_f	-	2.0	-	μs

*To avoid excessive heating of collector junction, perform this test with a sweep method.

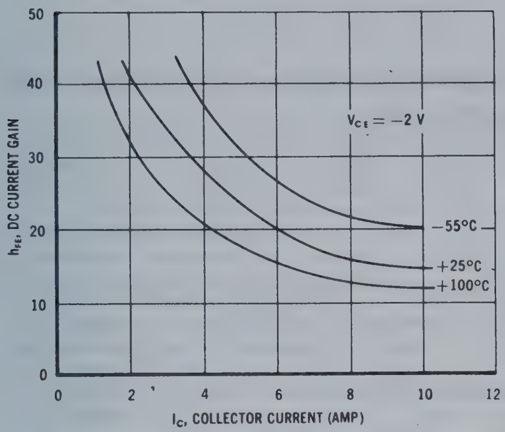
COLLECTOR CURRENT versus BASE CURRENT



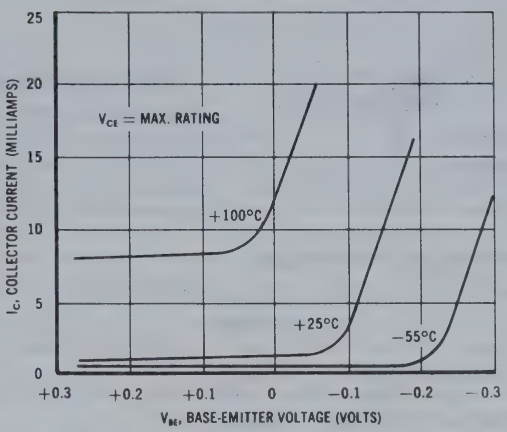
COLLECTOR CURRENT versus DRIVE VOLTAGE



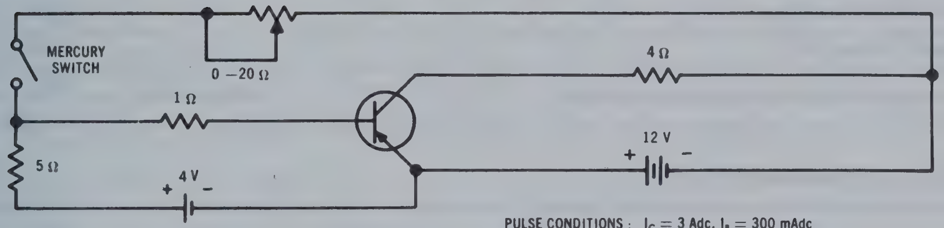
DC CURRENT GAIN versus COLLECTOR CURRENT



COLLECTOR CURRENT versus DRIVE VOLTAGE



SWITCHING TEST CIRCUIT



MERCURY SWITCH
0 −20 Ω
1 Ω
4 Ω
5 Ω
4 V
+
−
12 V
+
−

PULSE CONDITIONS ; $I_C = 3$ Adc, $I_B = 300$ mAdc

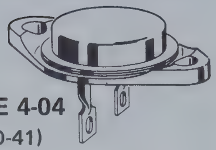
2N1099 (GERMANIUM)

For Specifications, See 2N277 Data.

2N1100 (GERMANIUM)

For Specifications, See 2N174 Data.

2N1120 (GERMANIUM)


CASE 4-04
(TO-41)

PNP germanium power transistor for military and industrial power applications.

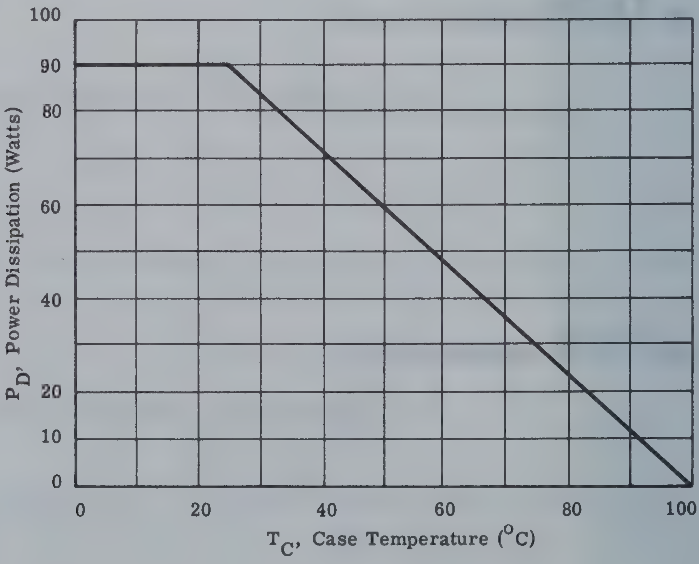
MAXIMUM RATINGS

Rating	Symbol	2N1120	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage	V_{CES}	70	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Emitter Current	I_E	15	Adc
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	90 1.2	Watts $W/^{\circ}C$
Operating Junction Temperature Range	T_J	-65 to +100	$^{\circ}C$

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^{\circ}C/W$

POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, V_{BE} = 0)	BV_{CES}	70	-	Vdc
Floating Potential (V_{CB} = 80 Vdc, I_E = 0) (Voltmeter Input Resistance = 10 meg. min.)	V_{EBF}	-	1.0	Vdc
Collector Cutoff Current (V_{CB} = 2 Vdc, I_E = 0)	I_{CBO}	-	0.3	mAdc
(V_{CB} = 30 Vdc, I_E = 0)			20	
(V_{CB} = 80 Vdc, I_E = 0)		-	15	
Emitter Cutoff Current (V_{BE} = 40 Vdc, I_C = 0)	I_{EBO}	-	5.0	mAdc
Base Current (V_{CE} = 2 Vdc, I_C = 5 Adc)	I_B	50	-	mAdc
(V_{CE} = 2 Vdc, I_C = 10 Adc)		200	500	
ON CHARACTERISTICS				
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	-	100	-
(I_C = 10.0 Adc, V_{CE} = 2.0 Vdc)		20	50	
Collector-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{BE(sat)}$	-	1.5	Vdc
Base-Emitter On Voltage (I_C = 10 Adc, V_{CE} = 2 Vdc)	$V_{BE(on)}$	-	2.0	Vdc
SMALL SIGNAL CHARACTERISTICS				
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	$f_{\alpha e}$	3.0	-	kHz

2N1131 (SILICON)

2N1131 JAN AVAILABLE

2N1131A

2N1991

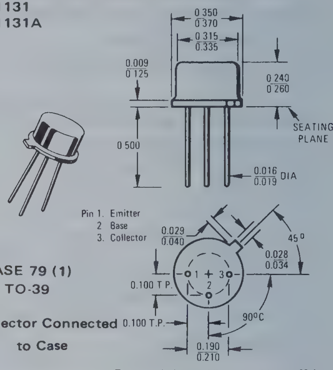
PNP SILICON ANNULAR TRANSISTORS

. . . designed for medium-speed switching and amplifier applications where low DC current gain is essential.

- Low DC Current Gain –
  h_{FE} = 45 (Max) @ I_C = 150 mAdc – 2N1131,A
- Turn-On Time – t_{on} = 45 ns (Max) – 2N1131A
- Turn-Off Time – t_{off} = 35 ns (Max) – 2N1131A

PNP SILICON AMPLIFIER AND SWITCHING TRANSISTORS

2N1131
2N1131A

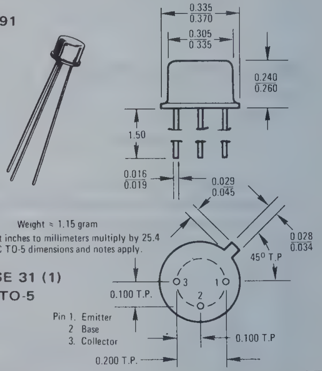

0.350
0.370
0.315
0.335
0.009
0.125
0.240
0.260
SEATING PLANE
0.500
0.016
0.019
DIA
Pin 1. Emitter
2. Base
3. Collector
0.029
0.040
45°
0.028
0.034
0.100 T.P.
1
2
3
90°C
0.100 T.P.
0.190
0.210

CASE 79 (1)
TO-39

Collector Connected to Case

To convert inches to millimeters multiply by 25.4.
All JEDEC TO-39 dimensions and notes apply.

2N1991


0.335
0.370
0.305
0.335
0.240
0.260
1.50
0.016
0.019
0.029
0.045
0.028
0.034
45° T.P.
0.100 T.P.
3
1
2
Pin 1. Emitter
2. Base
3. Collector
0.100 T.P.
0.200 T.P.

Weight ≈ 1.15 gram
To convert inches to millimeters multiply by 25.4
All JEDEC TO-5 dimensions and notes apply.

CASE 31 (1)
TO-5

*MAXIMUM RATINGS

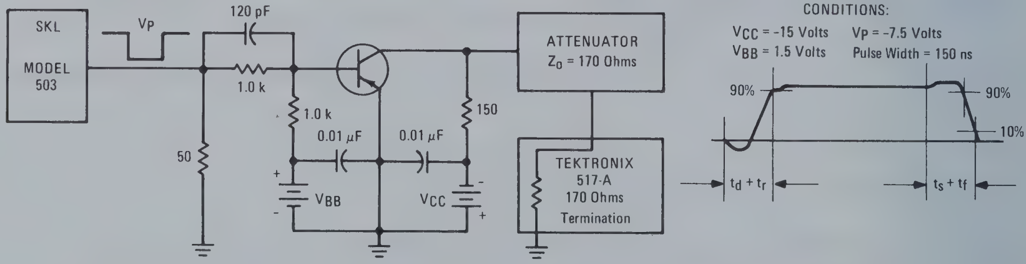
Rating	Symbol	2N1131	2N1131A	2N1991	Unit
Collector-Emitter Voltage	V_{CEO}	35	40	20	Vdc
Collector-Emitter Voltage	V_{CER}	50	50	–	Vdc
Collector-Base Voltage	V_{CB}	50	60	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	5.0	Vdc
Collector Current – Continuous	I_C	600	600	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.6 4.0	0.6 4.0	0.6 4.8	Watt mW/°C
Total Device Dissipation @ T_C = 25°C @ T_C = 100°C Derate above 25°C	P_D	2.0 1.0 13.3	2.0 1.0 13.3	2.0 1.0 16	Watts Watt mW/°C
Operating Junction Temperature Range	T_J	175	175	150	°C
Storage Temperature Range	T_{stg}	-65 to +200		-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	2N1131,A	2N1991	Unit
Thermal Resistance, Junction to Case	θ_{JC}	75	62.5	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	250	208	°C/W

*Indicates JEDEC Registered Data.

FIGURE 1 – SWITCHING TIME TEST CIRCUIT – 2N1131A


SKL
MODEL
503
Vp
120 pF
1.0 k
50
1.0 k
0.01 µF
0.01 µF
VBB
VCC
150
ATTENUATOR
Z0 = 170 Ohms
TEKTRONIX
517-A
170 Ohms
Termination
90%
90%
10%
td + tr
ts + tf

CONDITIONS:
V_{CC} = -15 Volts V_P = -7.5 Volts
V_{BB} = 1.5 Volts Pulse Width = 150 ns

2N1131, 2N1131A, 2N1991 (continued)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage(1)		$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N1131		35	–	
	2N1131A		40	–	
	2N1991		20	–	
Collector-Emitter Sustaining Voltage(1) (I_C = 100 mAdc, $R_{BE} \leq$ 10 ohms)	2N1131, 2N1131A	$V_{CER(sus)}$	50	–	Vdc
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 100 μAdc, I_E = 0)	2N1131A		60	–	
(I_C = 1.0 mAdc, I_E = 0)	2N1991		30	–	
Emitter-Base Breakdown Voltage (I_E = 1.0 mAdc, I_C = 0)	2N1131A	BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)	2N1131		–	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = +150°C)	2N1131		–	100	
(V_{CB} = 50 Vdc, I_E = 0)	2N1131		–	100	
(V_{CB} = 45 Vdc, I_E = 0)	2N1131A		–	0.5	
(V_{CB} = 45 Vdc, I_E = 0, T_A = +150°C)	2N1131A		–	50	
(V_{CB} = 10 Vdc, I_E = 0)	2N1991		–	5.0	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +150°C)	2N1991		–	200	
Emitter Cutoff Current		I_{EBO}			μAdc
(V_{BE} = 2.0 Vdc, I_C = 0)	2N1131		–	100	
(V_{BE} = 5.0 Vdc, I_C = 0)	2N1131A		–	100	
(V_{BE} = 1.0 Vdc, I_C = 0)	2N1991		–	200	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc)	2N1131, 2N1131A		15	–	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)	2N1991		15	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N1131, 2N1131A		20	45	
	2N1991		15	60	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	–	1.5	Vdc
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N1131, 2N1131A		–	1.3	
	2N1991		–	1.5	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product(2)		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N1131, 2N1131A		50	–	
	2N1991		40	–	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	2N1131, 2N1991		–	45	
(V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	2N1131A		–	30	
Input Capacitance		C_{ib}			pF
(V_{EB} = 0.5 Vdc, I_C = 0, f = 140 kHz)	2N1131		–	80	
(V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	2N1131A		–	80	
Input Impedance		h_{ib}			ohms
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		25	35	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		–	10	
Voltage Feedback Ratio		h_{rb}			X 10^{-4}
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		–	8.0	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		–	8.0	
Small-Signal Current Gain		h_{fe}			–
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		15	50	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		20	–	
Output Admittance		h_{ob}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		–	1.0	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1131, 2N1131A		–	5.0	
SWITCHING CHARACTERISTICS (Figure 1)					
Turn-On Time	2N1131A	t_{on}	–	45	ns
Turn-Off Time	2N1131A	t_{off}	–	35	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N1132,A (SILICON)

For Specifications, See 2N722 Data

2N1141 thru 2N1143 (GERMANIUM)

2N1142 JAN AVAILABLE

2N1195

2N1195 JAN AVAILABLE

CASE 31
(TO-5)

Collector connected to case

PNP germanium mesa transistors for amplifier, driver, oscillator and doubler applications.

MAXIMUM RATINGS

Rating	Symbol	2N1141	2N1142	2N1143	2N1195	Unit
Collector-Base Voltage	V_{CB}	35	30	25	30	Vdc
Emitter-Base Voltage	V_{EB}	1.0	0.7	0.5	1.0	Vdc
Collector Current-Continuous	I_C	100	100	100	40	mAdc
Base Current	I_B	50	50	50	-	mAdc
Emitter Current-Continuous	I_E	100	100	100	-	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_D	300 4.0	300 4.0	300 4.0	- -	mW mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	750 10	750 10	750 10	- -	mW mW/°C
Collector Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_C	- -	- -	- -	225 3.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100				°C

2N1141-2N1143, 2N1195 (continued)

TRANSISTOR SELECTION CHART

TYPE	Minimum BV_{CBO} @I_C = —100μ Adc, I_E = 0			Typical 100 MHz Noise Figure @ V_{CE} = —10Vdc, I_E = 1mAdc R_s = 75Ω			Minimum h_{fe} @ I_C = —10mAdc, V_{CE} = —10Vdc, f = 100 MHz		
	35 Vdc	30 Vdc	25 Vdc	4.0 db	4.5 db	5.0 db	12 db	10 db	8 db
2N1141	✓			✓			✓		
2N1142		✓			✓			✓	
2N1143			✓			✓			✓
2N1195		✓		✓			✓		

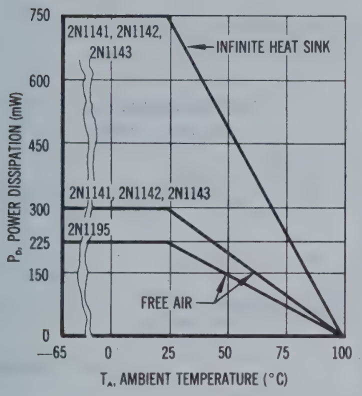
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N1141 2N1142 2N1143 2N1195	BV_{CBO}	35 30 25 30	45 45 45 45	- - - -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N1141 2N1142 2N1143 2N1195	BV_{EBO}	1.0 0.7 0.5 1.0	1.3 1.3 1.3 1.3	- - - -	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	- -	0.5 0.5	5.0 5.0	μAdc
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)		I_{EBO}	-	0.2	-	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N1141, 2N1142, 2N1143 2N1195	h_{FE}	10 -	25 25	- -	-
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 10 mAdc) (I_C = 50 mAdc, I_B = 10 mAdc)	2N1141, 2N1142, 2N1143 2N1195	$V_{CE(sat)}$	- -	0.185 0.185	2.0 -	Vdc

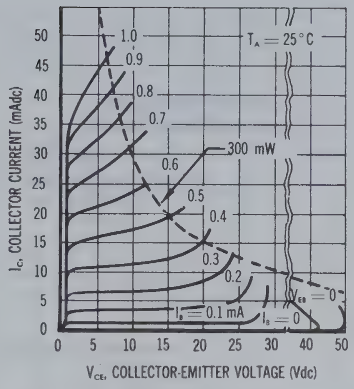
Characteristic	Symbol	Min	Typ	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Common-Base Cutoff Frequency (I_C = 10 mAdc, V_{CE} = 10 Vdc) All Types	$f_{\alpha b}$	-	1000	-	MHz
Collector Transition Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz) 2N1141	C_{Tc}	-	1.1	1.5	pF
2N1142, 2N1143, 2N1195		-	1.1	-	
Emitter Transition Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz) All Types	C_{Te}	-	2.5	-	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}				-
2N1141, 2N1195		12	18	-	
2N1142		10	18	-	
2N1143		8.0	18	-	
Small-Signal Current Gain (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz)	h_{fb}				-
2N1141, 2N1142, 2N1143		-	0.98	-	
2N1195		0.96	0.98	0.995	
Output Admittance (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz)	h_{ob}				μmhos
2N1141, 2N1142, 2N1143		-	10	-	
2N1195		-	10	20	
Input Impedance (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz)	h_{ib}				Ohms
2N1141, 2N1142, 2N1143		-	3.6	-	
2N1195		-	3.6	10	
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz)	h_{rb}				-
2N1141, 2N1142, 2N1143		-	0.0013	-	
2N1195		-	0.0013	0.003	
Collector-Base Time Constant (I_E = 3 mAdc, V_{CB} = 10 Vdc, f = 30 MHz) All Types	$r'_b C_c$	-	23	-	ps
Extrinsic Base Resistance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 250 MHz)	r'_b				Ohms
2N1141		-	65	70	
2N1142		-	80	-	
2N1143		-	110	-	
2N1195		-	65	80	
Collector Series Resistance (I_E = 10 mAdc, V_{CB} = 10 Vdc) All Types	r'_c	-	2.0	-	Ohms
Noise Figure (I_E = 0.8 mAdc, V_{CE} = 5 Vdc, R_S = 300 ohms, f = 4.5 MHz)	NF				dB
2N1141, 2N1195		-	3.0	-	
2N1142		-	3.5	-	
2N1143		-	4.0	-	
(I_E = 1 mAdc, V_{CE} = 10 Vdc, R_S = 75 ohms, f = 100 MHz)					
2N1141		-	4.0	-	
2N1142, 2N1195		-	4.5	-	
2N1143		-	5.0	-	
(I_E = 1 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz)					
2N1141		-	5.5	-	
2N1142, 2N1195		-	6.0	-	
2N1143		-	6.5	-	
Oscillator Efficiency (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 400 MHz)	η				%
2N1141		-	20	-	
2N1142		-	18	-	
2N1143		-	12	-	
2N1195		-	18	-	

2N1141-2N1143, 2N1195 (continued)

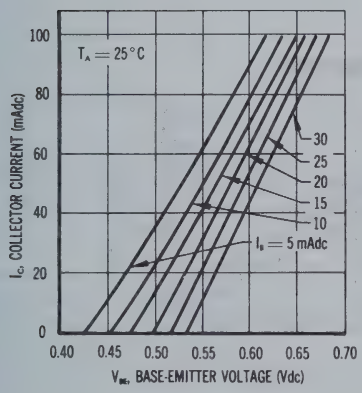
POWER-TEMPERATURE DERATING CURVE



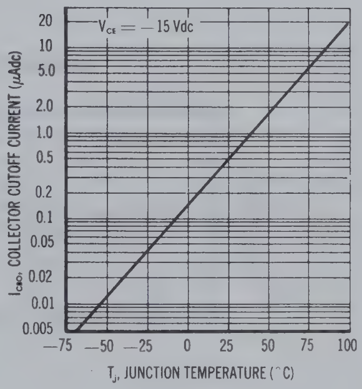
COLLECTOR CHARACTERISTICS, COMMON EMITTER



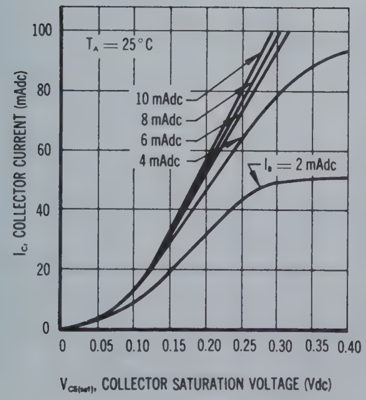
BASE CHARACTERISTICS, COMMON EMITTER



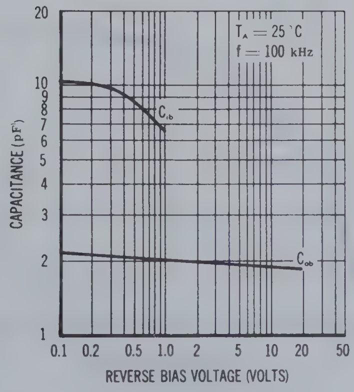
COLLECTOR CUTOFF CURRENT versus JUNCTION TEMPERATURE

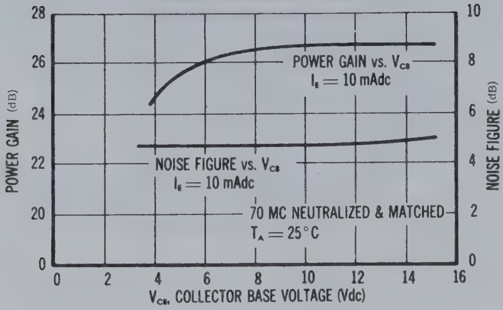


COLLECTOR SATURATION CHARACTERISTICS

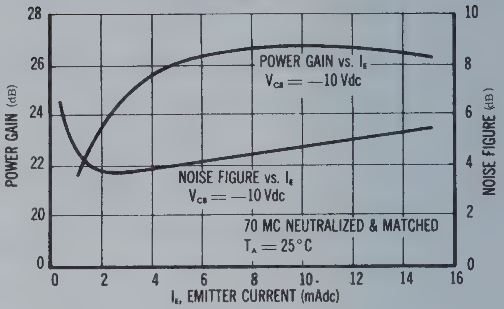


COLLECTOR INPUT AND OUTPUT CAPACITANCE versus VOLTAGE

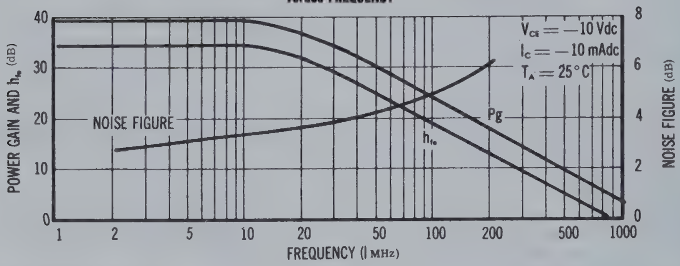




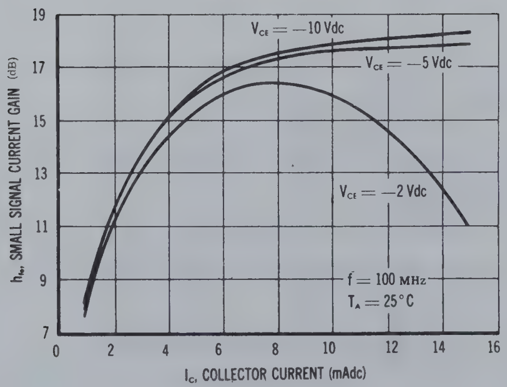
POWER GAIN AND NOISE FIGURE versus COLLECTOR-BASE VOLTAGE



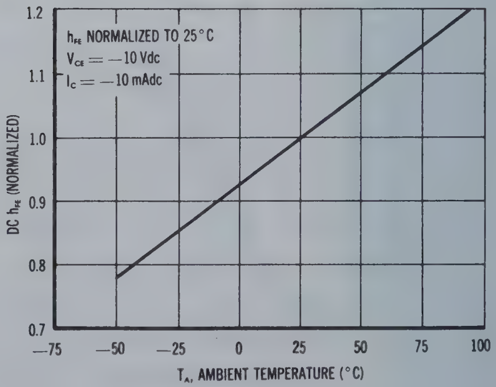
POWER GAIN AND NOISE FIGURE versus EMITTER CURRENT



COMMON EMITTER POWER GAIN, h_{fe}, AND NOISE FIGURE versus FREQUENCY



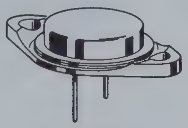
SMALL SIGNAL CURRENT GAIN (h_{fe}) versus COLLECTOR CURRENT



NORMALIZED h_{FE} versus AMBIENT TEMPERATURE

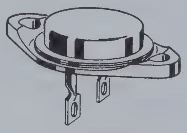
2N1162 thru 2N1167 (GERMANIUM)
2N1162A thru 2N1167A

PNP germanium power transistors for switching and amplifier applications in high reliability equipment.



CASE 11A
(TO-3 modified)

2N1162, A
2N1164, A
2N1166, A



CASE 4-04
(TO-41)

2N1163, A
2N1165, A
2N1167, A

MAXIMUM RATINGS

Apply also to standard, non-A series

Rating	Symbol	2N1162A 2N1163A	2N1164A 2N1165A	2N1166A 2N1167A	Units
Collector-Base Voltage	V_{CB}	50	80	100	Vdc
Collector-Emitter Voltage	V_{CES}	35	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	40	50	Vdc
Total Device Dissipation @ 25°C Derate above 25°C	P_D	106 1.25			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			°C

GROUP A ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = V_{CB}(max), I_E = 0)	I_{CBO1}	—	3.0	15	mA
Collector Cutoff Current (V_{CB} = 2 V, I_E = 0) (V_{CB} = 15 V, I_E = 0, T_C = 90°C) 2N1162A-3A* (V_{CB} = 30 V, I_E = 0, T_C = 90°C) 2N1164A-7A*	I_{CBO}	— — —	125 10 10	225 20 20	μA mA mA
Collector-Emitter Breakdown Voltage** (I_C = 500 mA, V_{EB} = 0) 2N1162A-3A* 2N1164A-5A* 2N1166A-7A*	BV_{CES}**	35 60 75	— — —	— — —	Vdc
Emitter Cutoff Current (V_{EB} = 12 V, I_C = 0)	I_{EBO}	—	0.5	1.2	mA
DC Forward Current Gain (V_{CE} = 1 V, I_C = 25 A) (V_{CE} = 2 V, I_C = 5 A)	h_{FE1} h_{FE}	15 —	25 65	— 125	—
Collector-Emitter Saturation Voltage (I_C = 25 A, I_B = 1.6 A)	$V_{CE(sat)}$	—	0.3	0.8	volts
Base-Emitter Saturation Voltage (I_C = 25 A, I_B = 1.6 A)	$V_{BE(sat)}$	—	0.7	1.7	volts
Common Emitter-Cutoff Frequency (V_{CE} = 2 V, I_C = 2 A)	$f_{\alpha e}$	—	4.0	—	kHz

*Characteristics apply also to corresponding, non-A type numbers
**Sweep Method: 1/2 cycle sine wave, 60 Hz

SWITCHING CHARACTERISTICS (Typical)

Saturated Collector Current	Pulsed Drive Base Current		Response times in μs		
	On	Off	$t_d + t_r$	t_s	t_f
5 amp	330 mA	100 mA	11	5.0	17
10 amp	660 mA	200 mA	15	4.0	20
25 amp	1650 mA	500 mA	19	3.0	18

FIGURE 1 — POWER TEMPERATURE DERATING CURVE

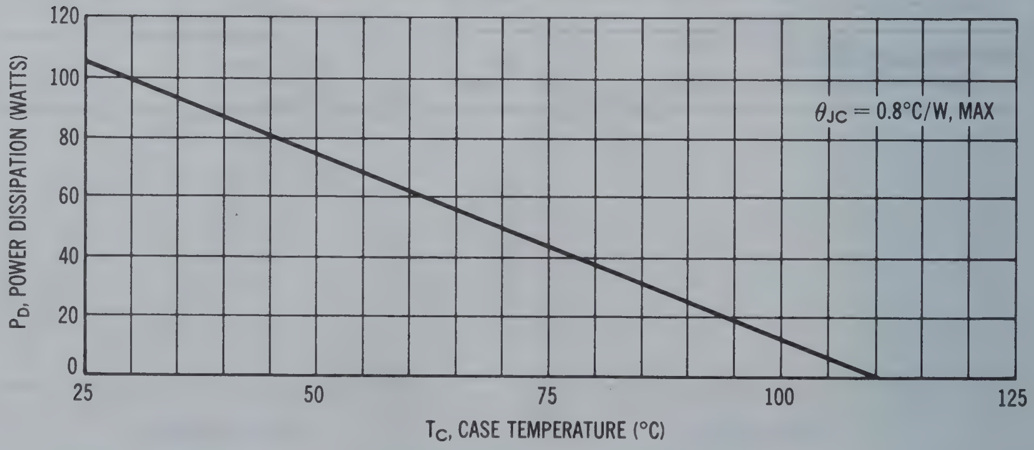
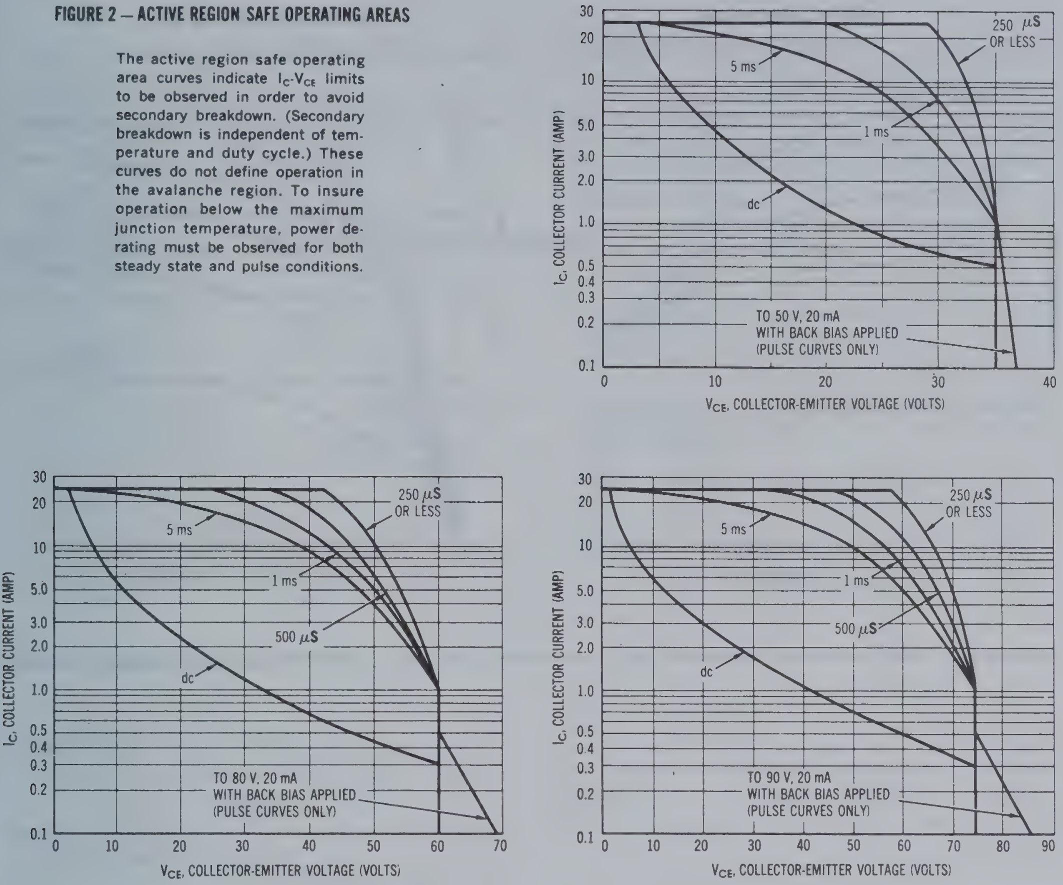


FIGURE 2 — ACTIVE REGION SAFE OPERATING AREAS

The active region safe operating area curves indicate I_C-V_{CE} limits to be observed in order to avoid secondary breakdown. (Secondary breakdown is independent of temperature and duty cycle.) These curves do not define operation in the avalanche region. To insure operation below the maximum junction temperature, power derating must be observed for both steady state and pulse conditions.



LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE

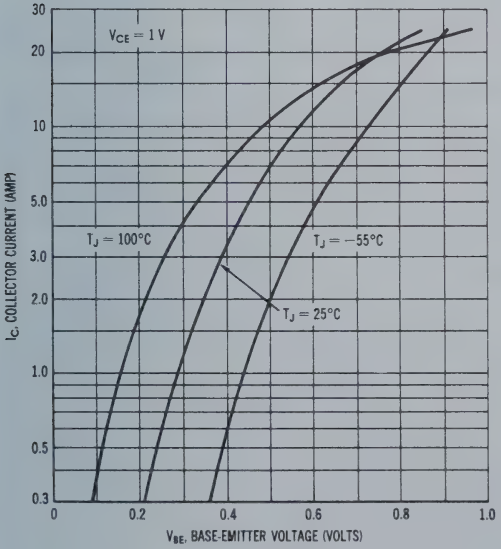


FIGURE 4 — INPUT ADMITTANCE

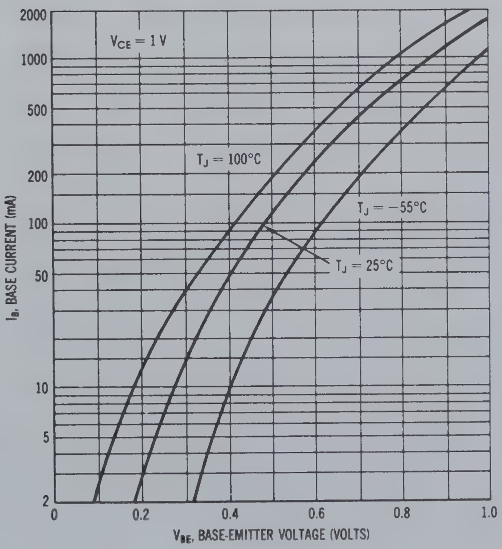


FIGURE 5 — CURRENT GAIN

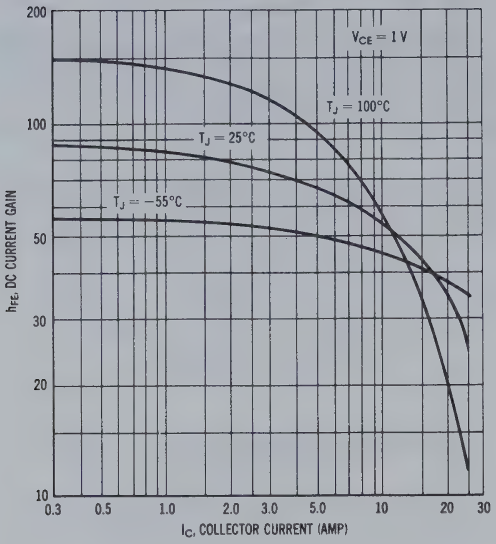
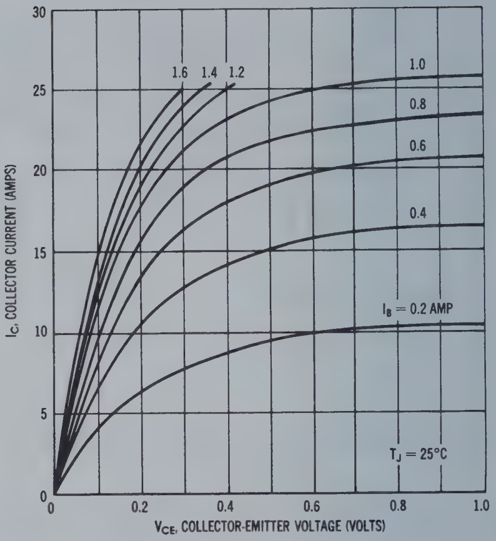


FIGURE 6 — SATURATION REGION



2N1175

FOR SPECIFICATIONS, SEE 2N1413-2N1415 DATA.

2N1185 thru 2N1188 (GERMANIUM)

PNP germanium transistors for high-gain audio amplifier and switching applications.

CASE 31 (1)
(TO-5)

All leads isolated from case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage 2N1185 2N1186-2N1188	V_{CB}	 45 60	Vdc
Collector-Emitter Voltage 2N1185 2N1186-2N1188	V_{CER}	 30 45	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current* (Continuous)	I_C	500*	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation in, Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance Junction to Ambient	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

*Limited by power dissipation

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

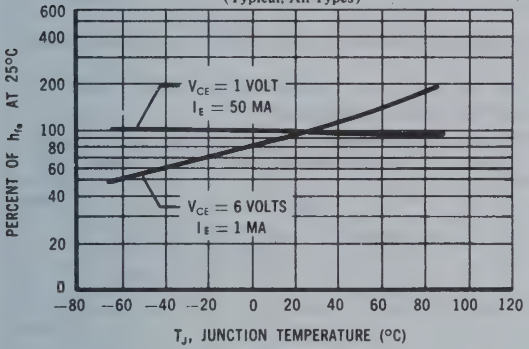
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 30 V, I_E = 0)	2N1185		-	3.0	10	
(V_{CB} = 45 V, I_E = 0)	2N1186 thru 2N1188		-	5.0	10	
(V_{CB} = 60 V, I_E = 0)	2N1186 thru 2N1188		-	-	50	
(V_{CB} = 10 V, I_E = 0, T_A = +71° C)	All Types		-	55	100	
Emitter-Base Cutoff Current (V_{EB} = 30 V, I_C = 0)		I_{EBO}	-	3.0	10	μAdc
Collector-Emitter Leakage Current		I_{CER}				μAdc
(V_{CE} = 30 V, R_{BE} = 10 K)	2N1185		-	-	600	
(V_{CE} = 45 V, R_{BE} = 10 K)	2N1186 thru 2N1188		-	-	600	
Collector-Emitter Punch-Thru Voltage		V_{pt}				Vdc
(V_F = 1.0 V,	2N1185		45	-	-	
VTVM Impedance ≥ 1 M ohm)	2N1186 thru 2N1188		60	-	-	
Output Capacitance (V_{CB} = 6 V, I_E = 0)		C_{ob}	-	10	25	pF
Noise Figure (V_{CE} = 4.5 V, I_E = 0.5 mA, R_g = 1 K, f = 1 kHz, Δf = 1 Hz)		NF	-	5.0	15	dB
Small Signal Current Gain Cutoff Frequency		$f_{\alpha b}$				MHz
(V_{CB} = 6 V, I_E = 1 mA)	2N1185		1.75	3.0	-	
	2N1186		0.75	1.5	-	
	2N1187		1.0	2.0	-	
	2N1188		1.25	2.5	-	
Input Impedance		h_{ib}				Ohms
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		27	35	37	
	2N1186		27	31	37	
	2N1187		27	34	37	
	2N1188		27	35	37	
Output Admittance		h_{ob}				μmho
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		0.2	0.50	0.7	
	2N1186		0.2	0.65	1.0	
	2N1187		0.2	0.60	0.9	
	2N1188		0.2	0.55	0.8	
Small Signal Current Gain		h_{fe}				-
(V_{CE} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		190	260	400	
	2N1186		30	49	70	
	2N1187		50	80	120	
	2N1188		100	130	225	
DC Current Transfer Ratio		h_{FE}				-
(V_{CE} = 1.0 V, I_C = 10 mA)	2N1185		130	170	-	
	2N1186		33	44	-	
	2N1187		45	75	-	
	2N1188		80	115	-	

ELECTRICAL CHARACTERISTICS (continued)

Characteristics		Symbol	Min	Typ	Max	Unit
Base-Emitter Input Voltage (V_{CE} = 1.0 V, I_C = 10 mA)	2N1185	V_{BE}	-	0.215	0.240	Vdc
	2N1186		-	0.245	0.270	
	2N1187		-	0.235	0.260	
	2N1188		-	0.225	0.250	
Collector-Emitter Saturation Voltage (I_C = 50 mA, I_B = 1.0 mA)	2N1185	V_{CE} (sat)	-	0.175	0.250	Vdc
(I_C = 50 mA, I_B = 2.5 mA)	2N1186		-	0.175	0.250	
(I_C = 50 mA, I_B = 1.67 mA)	2N1187		-	0.175	0.250	
(I_C = 50 mA, I_B = 1.25 mA)	2N1188		-	0.175	0.250	
Collector-Emitter Saturation Voltage (I_C = 100 mA, I_B = 2.0 mA)	2N1185	V_{CE} (sat)	-	0.250	0.500	Vdc
(I_C = 100 mA, I_B = 5.0 mA)	2N1186		-	0.250	0.500	
(I_C = 100 mA, I_B = 3.33 mA)	2N1187		-	0.250	0.500	
(I_C = 100 mA, I_B = 2.5 mA)	2N1188		-	0.250	0.500	

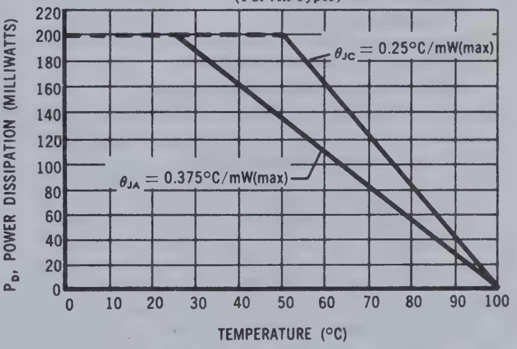
SMALL SIGNAL CURRENT GAIN(h_{fe}) versus TEMPERATURE

(Typical, All Types)

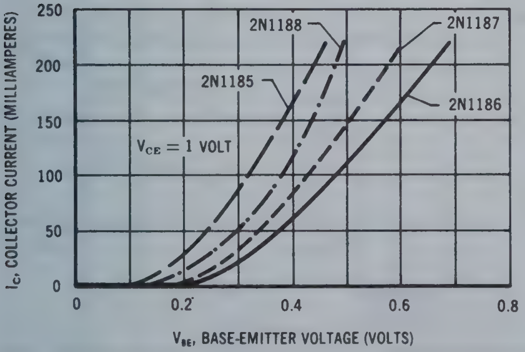


POWER-TEMPERATURE DERATING CURVE

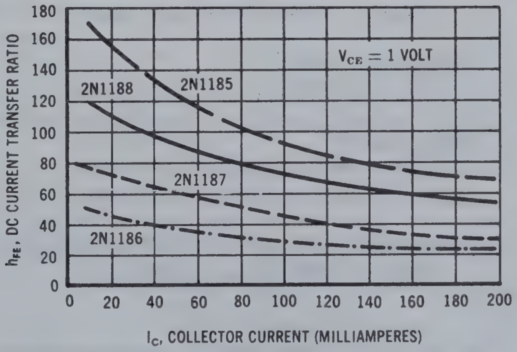
(For All Types)



OUTPUT CURRENT versus BASE DRIVE VOLTAGE



DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



2N1189 2N1190 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistors for high-gain audio amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CER}	30	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (Continuous)	I_C	500*	mAdc
Junction, Storage Temperature	T_J, T_{stg}	-65 to +100	°C
Collector Dissipation, Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

*Limited by power dissipation.

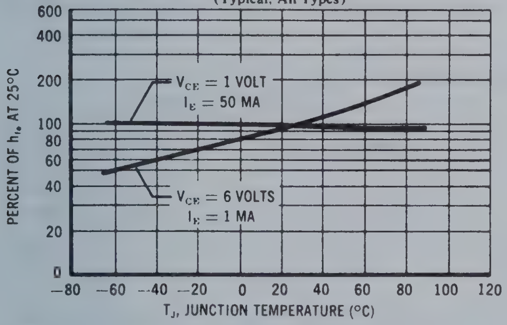
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current	I_{CBO}				μAdc
(V_{CB} = 30 Vdc, I_E = 0)		—	3.0	10	
(V_{CB} = 45 Vdc, I_E = 0)		—	—	50	
(V_{CB} = 10 Vdc, I_E = 0, T_A = + 71°C)		—	55	100	
Emitter-Base Cutoff Current (V_{EB} = 15 Vdc, I_C = 0)	I_{EBO}	—	3.0	10	μAdc
Collector-Emitter Leakage Current (V_{CE} = 30 Vdc, R_{BE} = 10K)	I_{CER}	—	—	600	μAdc
Collector-Emitter Punch-Thru Voltage (V_{EB} = 1 Vdc, VTVM Impedance ≥ 1 M ohm	V_{pt}	45	—	—	Vdc
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	12.0	25	pF
Noise Figure (V_{CE} = 4.5 Vdc, I_E = 0.5 mAdc R_g = 1 K, f = 1 kHz Δf = 1 Hz)	NF	—	5.0	15	dB
Small-Signal Current-Gain Cutoff Frequency (V_{CB} = 6 Vdc, I_E = 1 mAdc)	$f_{\alpha b}$				MHz
2N1189		1.75	3.5	—	
2N1190		2.25	4.5	—	

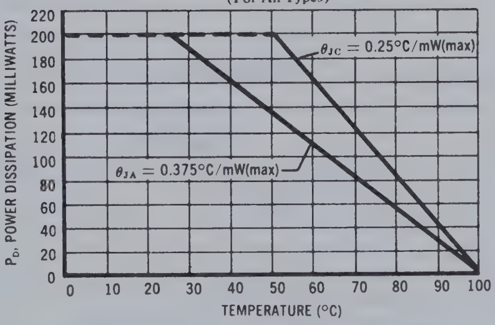
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
Input Impedance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ib}	27	31	37	Ohms
Output Admittance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ob}	0.1	—	0.9	μmho
Small Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N1189 2N1190	h_{fe}	 75 125	 120 190	 175 300	—
DC Current Transfer Ratio (V_{CE} = 1.0 Vdc, I_E = 10 mAdc) 2N1189 2N1190	h_{FE}	 60 100	 115 170	 — —	—
Base-Emitter Drive Voltage (V_{CE} = 1.0 Vdc, I_E = 10 mAdc) 2N1189 2N1190	V_{BE}	 — —	 0.24 0.22	 0.26 0.25	Vdc
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 1.5 mA) 2N1189 (I_C = 50 mAdc, I_B = 1.0 mA) 2N1190 (I_C = 100 mAdc, I_B = 3.0 mA) 2N1189 (I_C = 100 mAdc, I_B = 2.0 mA) 2N1190	V_{CE} (sat)	 — — — —	 0.14 0.15 0.17 0.19	 0.22 0.22 0.3 0.3	Vdc

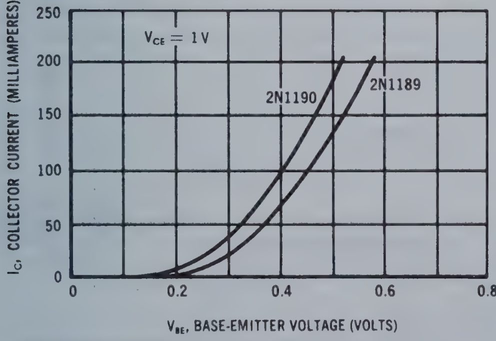
SMALL SIGNAL CURRENT GAIN(h_{fe}) versus TEMPERATURE
(Typical, All Types)



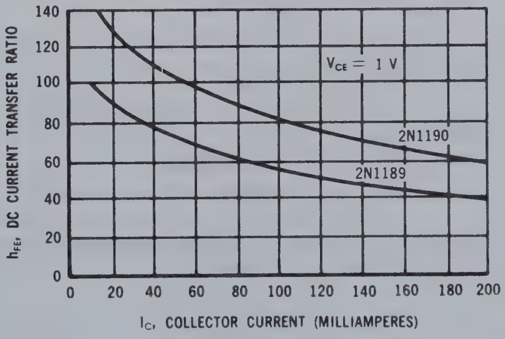
POWER-TEMPERATURE DERATING CURVE
(For All Types)



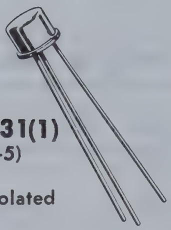
OUTPUT CURRENT versus BASE DRIVE VOLTAGE



DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



2N1191 thru 2N1194 (GERMANIUM)



CASE 31(1)
(TO-5)

All leads isolated

PNP germanium transistors for high-gain audio amplifier and switching applications.

MAXIMUM RATINGS

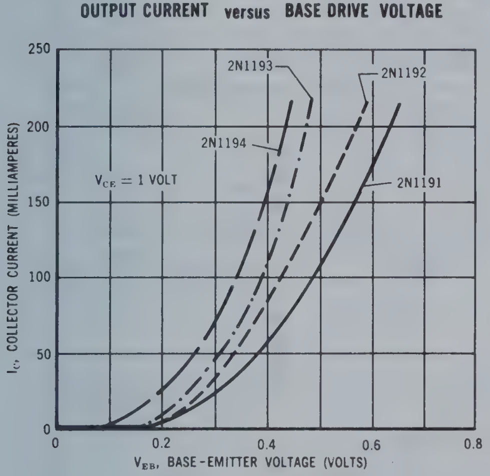
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CER}	25	Vdc
Emitter-Base Voltage	V_{EB}	25	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation in Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

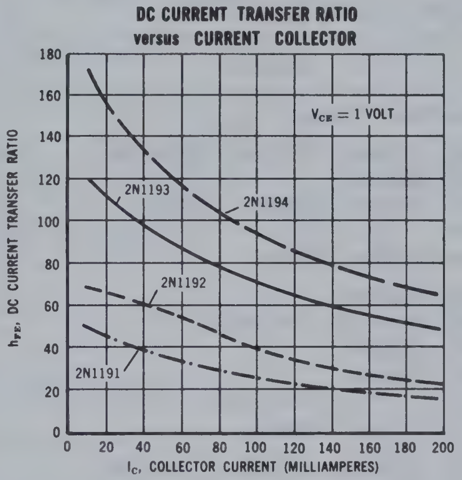
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

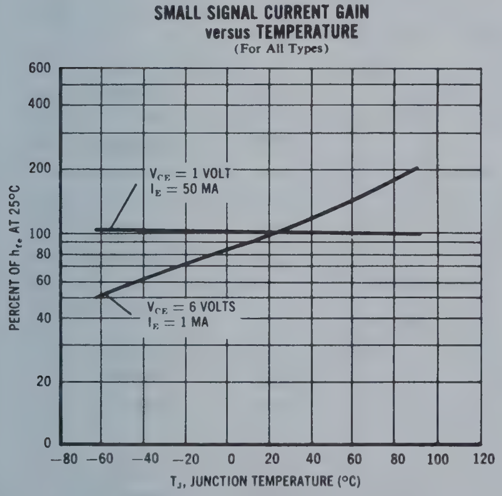
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				
(V_{CB} = 25 V, I_E = 0)			–	–	15	μAdc
(V_{CB} = 1.0 V, I_E = 0)			–	2.0	–	μAdc
Emitter-Base Cutoff Current (V_{EB} = 25 V, I_C = 0)		I_{EBO}	–	–	15	μAdc
Collector-Emitter Leakage Current (V_{CB} = 25 V, R_{BE} = 10 K)		I_{CER}	–	–	600	μAdc
Output Capacitance (V_{CE} = 6 V, I_E = 1.0 mA)		C_{ob}	–	20	–	pF
Noise Figure (V_{CE} = 4.5 V, I_E = 0.5 mA, f = 1 kHz, R_S = 100 ohms)		NF	–	10	–	dB
Small Signal Current Gain Cutoff Frequency (V_{CB} = 6 V, I_E = 1.0 mA)	2N1191	$f_{\alpha b}$	–	1.5	–	MHz
	2N1192		–	2.0	–	
	2N1193		–	2.5	–	
	2N1194		–	3.0	–	

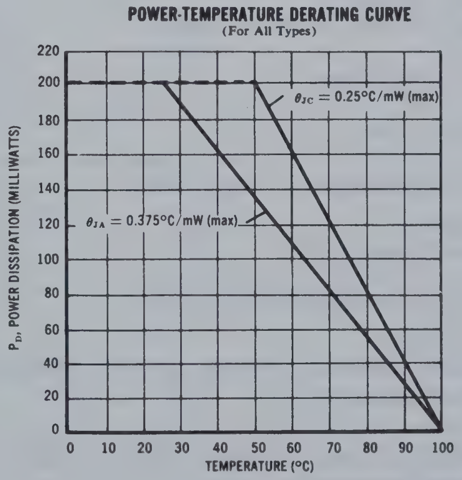
ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
Small Signal Current Gain (V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz)	2N1191	h_{fe}	30	40	70	–
	2N1192		50	75	125	
	2N1193		100	160	250	
	2N1194		190	280	500	
DC Current Gain (V_{CE} = 1 V, I_C = 10 mA)	2N1191	h_{FE}	20	–	80	–
	2N1192		40	–	135	
	2N1193		70	–	300	
	2N1194		125	–	600	
Small Signal Power Gain (V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz, matched)	2N1191	G_e	–	42	–	dB
	2N1192		–	44	–	
	2N1193		–	46	–	
	2N1194		–	48	–	
Base-Emitter Input Voltage (V_{CE} = 6 V, I_C = 1.0 mA)		V_{BE}	–	–	0.3	Vdc


OUTPUT CURRENT versus BASE DRIVE VOLTAGE


DC CURRENT TRANSFER RATIO versus CURRENT COLLECTOR


SMALL SIGNAL CURRENT GAIN versus TEMPERATURE (For All Types)


POWER-TEMPERATURE DERATING CURVE (For All Types)

2N1195

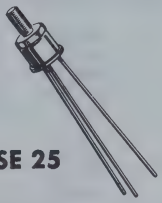
FOR SPECIFICATIONS, SEE 2N1141 DATA.

2N1204, A (GERMANIUM)
2N1494, A
2N1495
2N1496
2N2096
2N2097
2N2099
2N2100

PNP germanium epitaxial mesa transistors for high-speed, high-current switching in line and core driver applications.

CASE 31
(TO-5)

2N1204,A
2N1495
2N2099
2N2100



CASE 25

2N1494,A
2N1496
2N2096
2N2097

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage 2N1204, 2N1204A, 2N1494, 2N1494A 2N2096, 2N2099 2N1495, 2N1496, 2N2097, 2N2100	V_{CB}	 20 25 40	Vdc
Collector-Emitter Voltage 2N2096, 2N2099 2N1204, 2N1204A, 2N1494A 2N2097, 2N2100 2N1495, 2N1496	V_{CEO}	 12 15 20 25	Vdc
Collector-Emitter Voltage 2N1204, 2N1204A, 2N1494, 2N1494A 2N2096, 2N2099 2N1495, 2N1496, 2N2097, 2N2100	V_{CES}	 20 25 40	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_C = 25°C$ All Types Derate above 25°C	P_D	 750 10	 mW mW/°C
Total Device Dissipation @ $T_A = 25°C$ TO-5 Case 2N1204, 2N1204A, 2N1495, 2N2099, 2N2100 Derate above 25°C Case 25 2N1494, 2N1494A, 2N1496, 2N2096, 2N2097 Derate above 25°C	P_D	 300 4.0 500 6.67	 mW mW/°C mW mW/°C
Operating Junction and Storage Temperature Range	T_J T_{stg}	-65 to +100	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 100 μAdc, I_E = 0)	2N1204, 2N1204A, 2N1494, 2N1494A		20	40	–	
	2N2096, 2N2099		25	–	–	
	2N1495, 2N1496, 2N2097, 2N2100		40	–	–	
Collector-Emitter Breakdown Voltage		BV_{CES}				Vdc
(I_C = 100 μAdc, V_{BE} = 0)	2N1204, 2N1204A, 2N1494, 2N1494A		20	40	–	
	2N2096, 2N2099		25	–	–	
	2N1495, 2N1496, 2N2097, 2N2100		40	–	–	
Collector-Emitter Breakdown Voltage		BV_{CEO}				Vdc
(I_C = 2 mAdc, I_B = 0)	2N1204, 2N1204A, 2N1494, 2N1494A		15	25	–	
(I_C = 10 mAdc, I_B = 0)	2N2096, 2N2099		12	–	–	
	2N2097, 2N2100		20	–	–	
	2N1495, 2N1496		25	–	–	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 1 mAdc, I_C = 0)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A		4.0	–	–	
(I_E = 10 mAdc, I_C = 0)	2N2096, 2N2097, 2N2099, 2N2100		4.0	–	–	
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 5 Vdc, I_E = 0)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A		–	0.4	7.0	
(V_{CB} = 12 Vdc, I_E = 0)	2N2096, 2N2099		–	–	12	
(V_{CB} = 15 Vdc, I_E = 0)	2N2097, 2N2100		–	–	12	
Emitter Cutoff Current		I_{EBO}				μAdc
(V_{BE} = 0.5 Vdc, I_C = 0)	2N1494 thru 2N1496, 2N1494A		–	–	50	
(V_{BE} = 1 Vdc, I_C = 0)	2N2096, 2N2097, 2N2099, 2N2100		–	10	50	
DC Current Gain		h_{FE}				–
(I_C = 200 mAdc, V_{CE} = 0.5 Vdc)	2N1204A, 2N1494A, 2N1495, 2N1496		25	–	–	
(I_C = 200 mAdc, V_{CE} = 1 Vdc)	2N2097, 2N2100		30	70	–	
(I_C = 400 mAdc, V_{CE} = 1.5 Vdc)*	2N1204, 2N1494, 2N2096, 2N2099		15	35	–	
	2N2097, 2N2100		20	50	–	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)	2N2097, 2N2100		–	–	0.3	
(I_C = 200 mAdc, I_B = 10 mAdc)	2N1204, 2N1204A, 2N1494, 2N1494A		–	–	0.4	
	2N2097, 2N2100		–	–	0.5	
	2N2096, 2N2099		–	–	0.6	
(I_C = 200 mAdc, I_B = 20 mAdc)	2N1495, 2N1496		–	–	0.3	
(I_C = 400 mAdc, I_B = 25 mAdc)**	2N1204A, 2N1494A, 2N1495, 2N1496		–	–	0.7	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)	2N2097, 2N2100		–	–	0.5	
(I_C = 200 mAdc, I_B = 10 mAdc)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A		0.40	0.60	0.72	
	2N2097, 2N2100		–	–	0.8	
	2N2096, 2N2099		–	–	0.9	
Collector Output Capacitance		C_{ob}				pF
(V_{CB} = 10 Vdc, I_E = 0, f = 4 MHz)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A		–	3.5	6.5	
	2N2096, 2N2097, 2N2099, 2N2100		–	3.5	20	
Input Capacitance		C_{ib}				pF
(V_{BE} = 1 Vdc, I_C = 0, f = 4 MHz)	All Types		–	8.0	50	
AC Current Gain		h_{fe}				–
(I_C = 20 mA, V_{CE} = 10 V, f = 100 MHz)	2N1204, 2N1204A, 2N1494, 2N1494A		1.1	2.0	–	
	2N1495, 2N1496		1.5	–	–	
Rise Time (Figure 5)		t_r				ns
	2N2097, 2N2100		–	–	20	
	2N1204, 2N1204A, 2N1494, 2N1494A, 2N2096, 2N2099		–	–	35	
	2N1495, 2N1496		–	–	55	
Minority Carrier Storage Time Constant (Figure 4)		τ_s				ns
	2N1204, 2N1204A, 2N1494, 2N1494A		–	30	75	
	2N1495, 2N1496		–	–	90	
Storage Time (Figure 6)		t_s				ns
	2N2097, 2N2100		–	–	50	
	2N2096, 2N2099		–	–	70	
Fall Time (Figure 6)		t_f				ns
	2N2097, 2N2100		–	–	40	
	2N2096, 2N2099		–	–	60	

*Pulse Test: Pulse width ≤ 1 ms, Duty cycle ≤ 6%

**Pulse Test: Pulse width ≤ 5 ms, Duty cycle ≤ 2%

FIGURE 1 — TYPICAL RISE AND FALL TIME BEHAVIOR

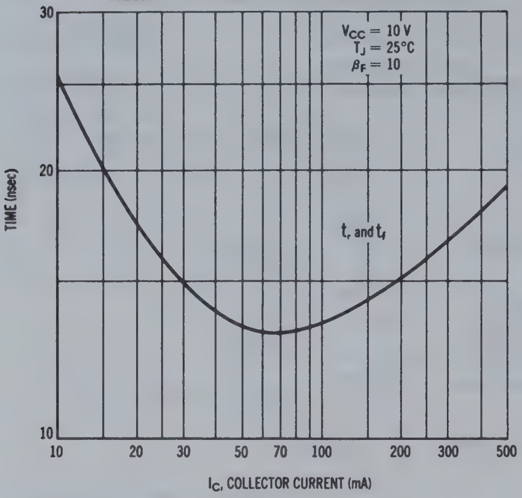


FIGURE 2 — STORAGE TIME VARIATIONS

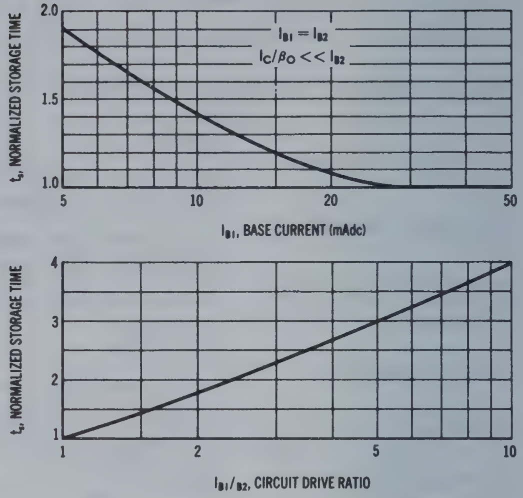


FIGURE 3 — TOTAL CONTROL CHARGE

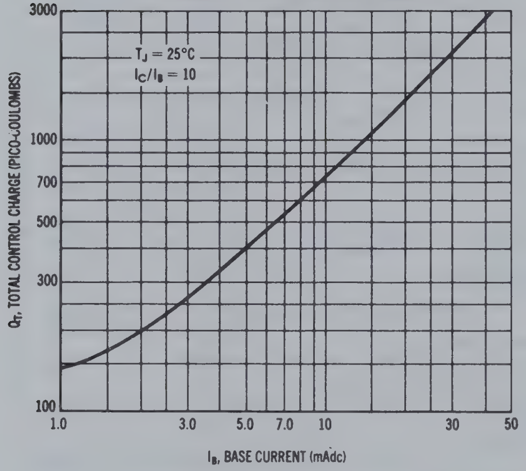
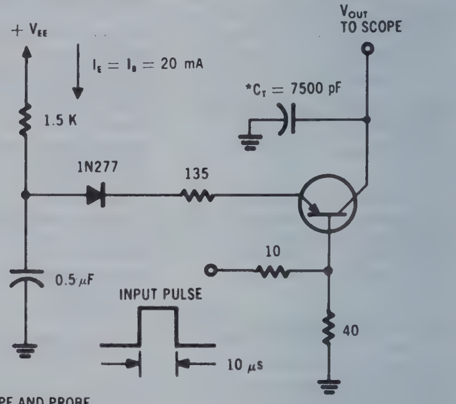


FIGURE 4 — CARRIER STORAGE TIME CONSTANT TEST CIRCUIT

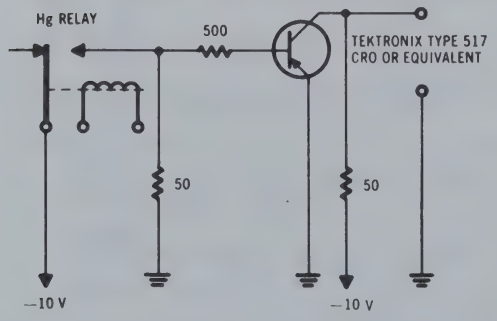


+ V_{EE}
$I_E = I_B$ = 20 mA
V_{OUT} TO SCOPE
*C_T = 7500 pF
1.5 K
1N277
135
10
0.5 μF
INPUT PULSE
40
10 μs

*ADD SCOPE AND PROBE CAPACITANCE TO C_T FOR CORRECT CALCULATION OF τ_s (K's).

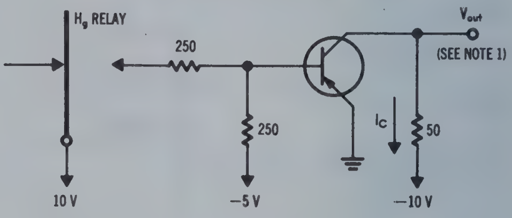
$$\tau_s = \frac{C_T V_{OUT}}{I_E}$$

FIGURE 5 — RISE TIME TEST CIRCUIT



Hg RELAY
500
TEKTRONIX TYPE 517 CRO OR EQUIVALENT
50
50
−10 V
−10 V

FIGURE 6 — STORAGE AND FALL TIME TEST CIRCUIT



H_g RELAY
250
V_{out}
(SEE NOTE 1)
250
I_C
50
10 V
−5 V
−10 V

NOTE 1: SCOPE IMPEDANCE SUFFICIENTLY HIGH SO THAT DOUBLING OR HALVING ITS VALUE DOES NOT CHANGE THE READING.

SCOPE RISE TIME FAST ENOUGH SO THAT DOUBLING OR HALVING ITS VALUE DOES NOT CHANGE THE READING.

FIGURE 7 — COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

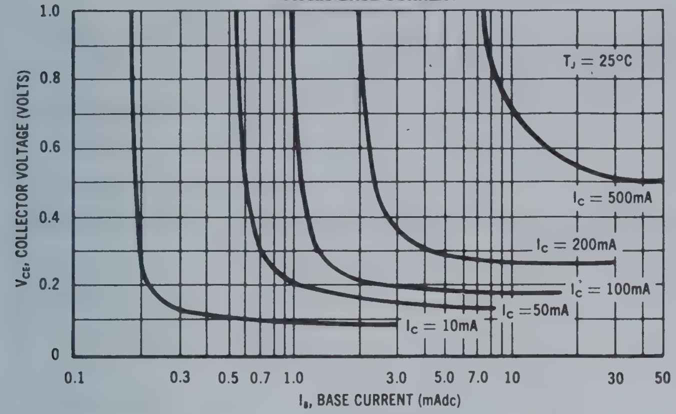


FIGURE 8 — BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

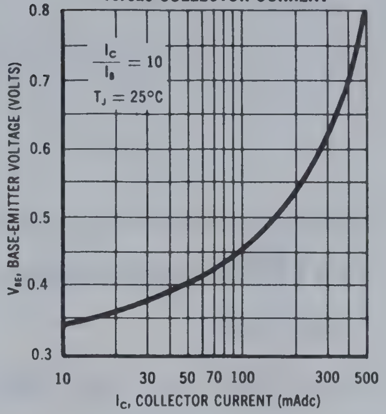


FIGURE 9 — TEMPERATURE COEFFICIENTS

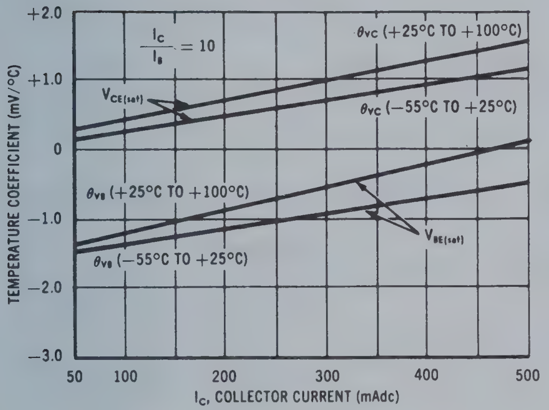


FIGURE 10 — NORMALIZED CURRENT GAIN CHARACTERISTICS

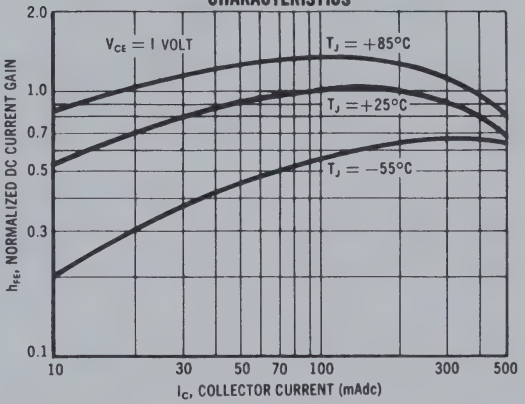
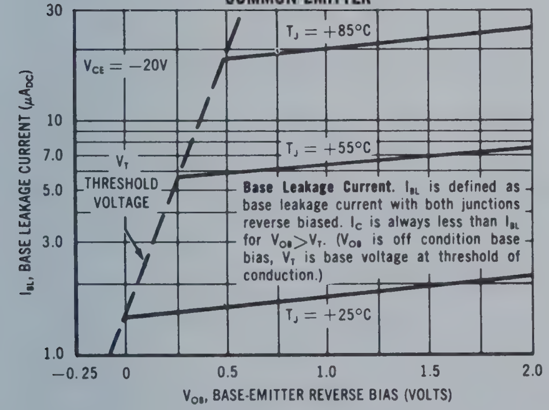
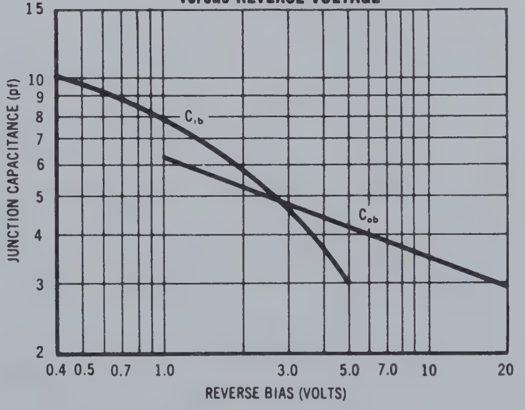


FIGURE 11 — LEAKAGE CHARACTERISTICS COMMON EMITTER



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of conduction.)

FIGURE 12 — JUNCTION CAPACITANCE versus REVERSE VOLTAGE



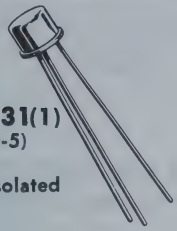
2N1358, A (GERMANIUM)

For Specifications, See 2N174 Data.

2N1359 (GERMANIUM)
2N1360
2N1362 thru 2N1365

For Specifications, See 2N375 Data.

2N1408 (GERMANIUM)



CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for high voltage neon driver, solenoid and relay driver circuits.

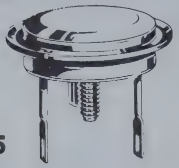
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Vdc
Collector-Emitter Voltage	V_{CES}	50	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Collector Current	I_C	200	mA
Collector Dissipation at $T_A = 25°C$ derating factor	P_D	150 2.0	mW mW/°C
Junction Temperature Range	T_J	-65 to +100	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	---	7.0	μAdc
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	---	7.0	μAdc
Collector-Emitter Leakage Current (V_{CB} = 50 Vdc, R_{BE} = 0)	I_{CES}	---	150	μAdc
Collector-Base Breakdown Voltage (I_C = 25 μAdc, I_E = 0)	BV_{CBO}	50	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 25 μAdc, I_C = 0)	BV_{EBO}	10	---	Vdc
Collector-Emitter Punch-Thru Voltage (I_E = 25 μAdc)	V_{pt}	50	---	Vdc
Base-Emitter Input Voltage (I_B = 1.0 mAdc, V_{CE} = 1.0 Vdc)	V_{BE}	---	0.6	Vdc
DC Current Gain (V_{CE} = 1 Vdc, I_B = 1 mAdc)	h_{FE}	10	---	---
Small Signal Current Gain (V_{CE} = 5.0 Vdc, I_E = 1.0 mA, f = 1 kHz)	h_{fe}	10	---	---
Output Admittance (V_{CB} = 5.0 Vdc, I_E = 1.0 mA, f = 1 kHz)	h_{ob}	---	2.0	μmhos

2N1412 (GERMANIUM)
2N1412A



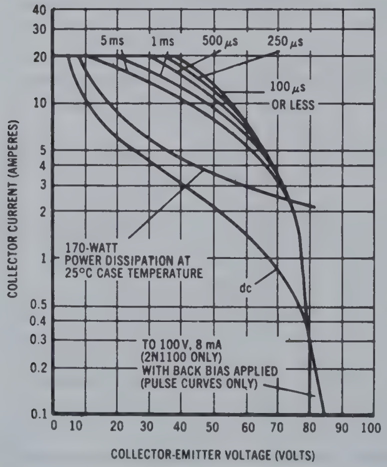
CASE 5
(TO-36)

PNP germanium power transistors for high-voltage power amplifier and switching applications in military and industrial equipment.

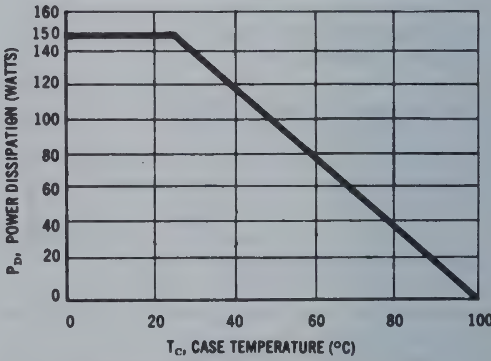
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	100	Vdc
Collector-Emitter Voltage	V_{CES}	80	Vdc
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Emitter-Base Voltage	V_{EB}	60	Vdc
Emitter Current (Continuous)	I_E	15	Amp
Base Current (Continuous)	I_B	4.0	Amp
Junction & Storage Temperature	T_{stg}	-65 to +100	^{o}C
Thermal Resistance	θ_{JC}	0.5	^{o}C/W

SAFE OPERATING AREA



POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 100°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{100° - T_C}{0.5}$$

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

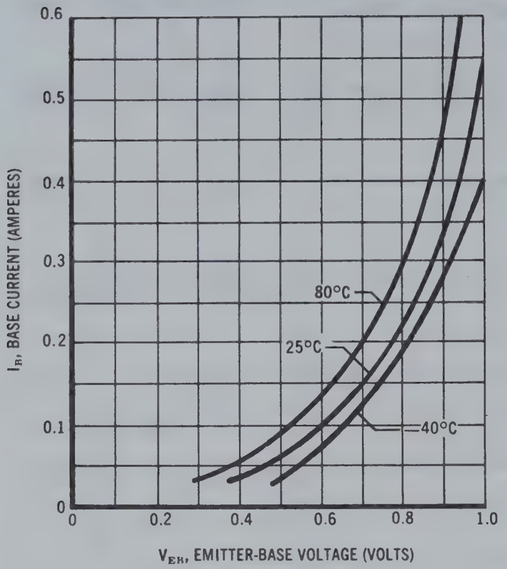
2N1412 (continued)

ELECTRICAL CHARACTERISTICS

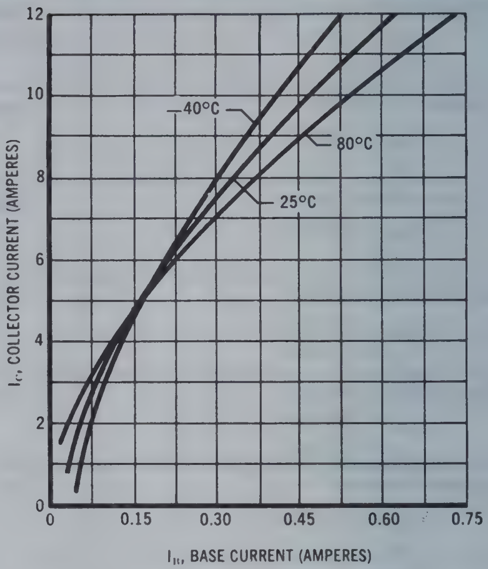
Characteristic	Symbol	Minimum	Maximum	Unit
Emitter Cutoff Current V_{EB} = −2.0 Vdc I_C = 0	I_{EBO}	—	200	μAdc
Emitter Cutoff Current V_{EB} = −60 Vdc I_C = 0	I_{EBO}	—	10	mAdc
Collector Cutoff Current V_{CB} = −2.0 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector Cutoff Current V_{CB} = −100 Vdc I_E = 0	I_{CBO}	—	10	mAdc
Emitter-Base Voltage V_{CE} = −2.0 Vdc I_C = −1.2 Adc	V_{EB}		0.5	Vdc
Emitter-Base Voltage V_{CE} = −2.0 Vdc I_C = −5.0 Adc	V_{EB}		0.9	Vdc
Floating Potential V_{CB} = −100 Vdc I_E = 0 (Voltmeter input resistance = 10 Megohm min)	V_{fl}		1.0	Vdc
Collector-Emitter Saturation Voltage I_C = −12 Adc I_B = −2.0 Adc	$V_{CE(SAT)}$		0.7	Vdc
Forward Current Transfer Ratio* V_{CE} = −2.0 Vdc I_C = −15 Adc	h_{FE}	10	—	—
Forward Current Transfer Ratio V_{CE} = −2.0 Vdc I_C = −5.0 Adc	h_{FE}	25	50	—
Collector-Emitter Breakdown Voltage* I_C = −1 Adc I_B = 0	BV_{CEO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* V_{EB} = 0 I_C = 300 mA	BV_{CES}	80	—	Vdc
Small-Signal Short-Circuit Forward-Current Transfer Ratio Cutoff Frequency V_{CE} = −12 Vdc I_C = −5.0 Adc	$f_{\alpha e}$	5.0	—	kHz
High-Temperature Operation Emitter Cutoff Current T_C = +71°C min V_{EB} = −30 Vdc	I_{EBO}	—	6.0	mAdc
Collector Cutoff Current V_{CB} = −30 Vdc I_E = 0	I_{CBO}	—	6.0	mAdc

*Test by sweep method with a short duty cycle (about 1%) to avoid excessive heating.

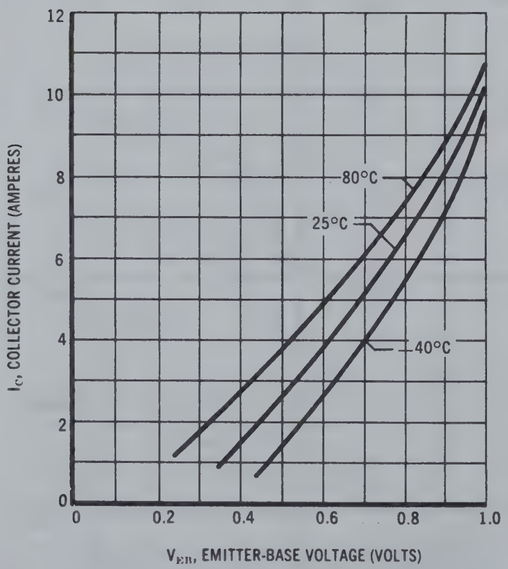
INPUT CHARACTERISTICS



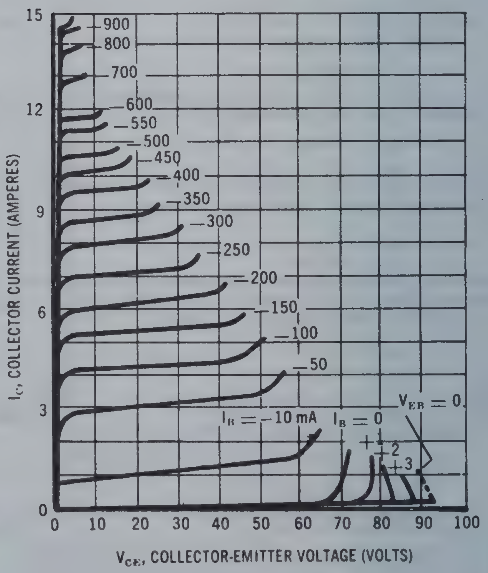
CURRENT TRANSFER CHARACTERISTICS



TRANSCONDUCTANCE CHARACTERISTICS

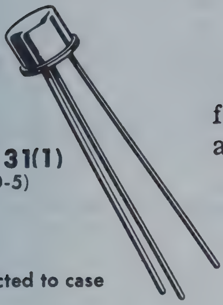


OUTPUT CHARACTERISTICS



2N1413 thru 2N1415 (GERMANIUM)

2N1175



CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for general-purpose low-frequency amplifier and switching applications. Characteristic curves similar to 2N524-2N527 series.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	35	Vdc
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_j & T_{stg}	-65 to +100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = 30 Vdc, I_E = 0	I_{CBO}	–	12	μAdc
Emitter Cutoff Current V_{EB} = 10 Vdc, I_C = 0	I_{EBO}	–	10	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	BV_{CER}	25	–	Vdc
Punch-Thru Voltage	V_{pt}	25	–	Vdc
DC Current Gain I_C = 20 mAdc, V_{CE} = 1 Vdc	h_{FE}			
2N1413		25	42	–
2N1414		34	65	
2N1415		53	90	
2N1175		70	140	

2N1413 thru 2N1415, 2N1175 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
DC Current Gain I_C = 100 mAdc, V_{CE} = 1 Vdc	h_{FE}			
2N1413		23	–	–
2N1414		30	–	
2N1415		47	–	
2N1175		62	–	
Base Input Voltage V_{CE} = 1 Vdc, I_C = 20 mAdc	V_{BE}			
2N1175		–	260	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	–	40	pF
Frequency Cutoff V_{CE} = 5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			
2N1413		0.8	–	MHz
2N1414		1.0	–	
2N1415		1.3	–	
2N1175		1.5	–	
Small-Signal Short-Circuit Forward-Transfer Current Ratio V_{CE} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{fe}			
2N1413		20	41	–
2N1414		30	64	
2N1415		44	88	
2N1175		60	120	
Small-Signal Open Circuit Output Admittance V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ob}			
2N1413		0.10	1.3	µmh
2N1414		0.10	1.2	
2N1415		0.10	1.0	
2N1175		0.10	0.9	
Small-Signal Open-Circuit Reverse-Transfer Voltate Ratio V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{rb}			
2N1413		1.0	10	$X10^{-4}$
2N1414		1.0	11	
2N1415		1.0	12	
2N1175		1.0	14	
Small-Signal Short-Circuit Input Impedance V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ib}			
2N1413		26	36	µmhos
2N1414		26	35	
2N1415		26	33	
2N1175		26	31	

2N1420

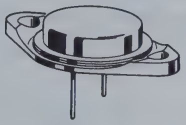
For Specifications, See 2N718 Data.

2N1494, A, 2N1495, 2N1496

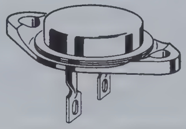
For Specifications, See 2N1204 Data.

2N1529 thru 2N1538 (GERMANIUM)
2N1529A thru 2N1532A, 2N1534A thru 2N1537A

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP1529, A etc. (TO-41 package)

MAXIMUM RATINGS

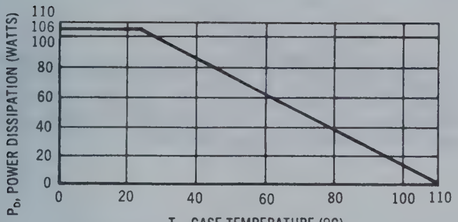
Rating	Symbol	2N1529 2N1534	2N1530 2N1535	2N1531 2N1536	2N1532 2N1537	2N1533 2N1538	Units
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	120	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEO}	20	30	40	50	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	120	Vdc
Emitter -Base Voltage	V_{EB}	20	30	40	50	60	Vdc
Collector Current (Continuous)	I_C	5.0					Amp
Collector Current (Peak)	I_C	10					Amp
Junction Temperature Range	T_J	-65 to +110					°C
Total Device Dissipation (25°C Case Temperature)	P_D	106					Watts
Thermal Resistance	θ_{JC}	0.8					°C/W

2N1529 thru 2N1538 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise specified.)
Characteristics apply to corresponding "A" type numbers also.

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO1}			mA
(V_{CB} = 25V)	2N1529, 2N1534		—	2.0	
(V_{CB} = 40V)	2N1530, 2N1535		—	2.0	
(V_{CB} = 55V)	2N1531, 2N1536		—	2.0	
(V_{CB} = 65V)	2N1532, 2N1537		—	2.0	
(V_{CB} = 80V)	2N1533, 2N1538		—	2.0	
Collector-Base Cutoff Current		I_{CBO}			mA
(V_{CB} = 2V)			—	0.2	
(V_{CB} = 1 2 BV_{CES} rating; T_C = +90°C)			—	20	
Emitter-Base Cutoff Current (V_{EB} = 12V)		I_{EBO}	—	0.5	mA
Collector-Emitter Breakdown Voltage		BV_{CES}			volts
(I_C = 500 mA, V_{EB} = 0)	2N1529, 2N1534		30	—	
	2N1530, 2N1535		45	—	
	2N1531, 2N1536		60	—	
	2N1532, 2N1537		75	—	
	2N1533, 2N1538		90	—	
Collector-Emitter Leakage Current (V_{BE} = 1V, V_{CE} @ rated BV_{CBO})		I_{CEX}	—	20	mA
Collector-Emitter Breakdown Voltage		BV_{CEO}			volts
(I_C = 500 mA, I_B = 0)	2N1529, 2N1534		20	—	
	2N1530, 2N1535		30	—	
	2N1531, 2N1536		40	—	
	2N1532, 2N1537		50	—	
	2N1533, 2N1538		60	—	
Collector-Base Breakdown Voltage		BV_{CBO}			volts
(I_C = 20 mA)	2N1529, 2N1534		40	—	
	2N1530, 2N1535		60	—	
	2N1531, 2N1536		80	—	
	2N1532, 2N1537		100	—	
	2N1533, 2N1538		120	—	
Current Gain		h_{FE1}			—
(V_{CE} = 2V, I_C = 3A)	2N1529 - 2N1533		20	40	
	2N1534 - 2N1538		35	70	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			volts
(I_C = 3A, I_B = 300 mA)	2N1529 - 2N1533		—	1.7	
	2N1534 - 2N1538		—	1.5	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			volts
(I_C = 3A, I_B = 300 mA)	2N1529 - 2N1533		—	1.5	
	2N1534 - 2N1538		—	1.2	
Transconductance		g_{FE}			mhos
(V_{CE} = 2V, I_C = 3A)	2N1529 - 2N1533		1.2	—	
	2N1534 - 2N1538		1.5	—	

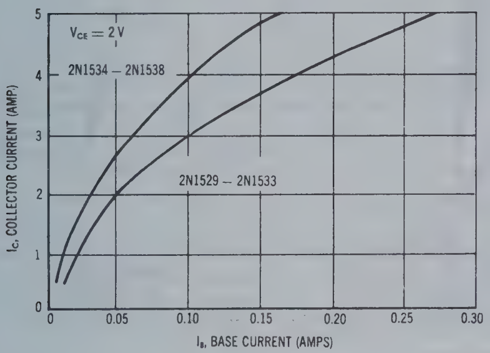
POWER-TEMPERATURE DERATING CURVE



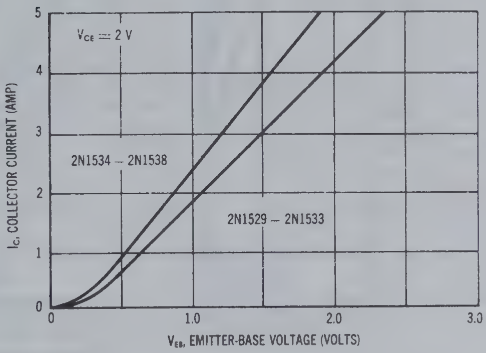
The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For dc or frequencies below 25 Hz the transistor must be operated within the constant $P_D = V_C \times I_C$ hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^{\circ} - T_c}{0.8}$$

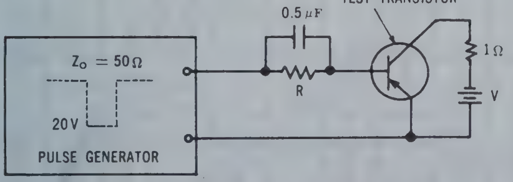
COLLECTOR CURRENT versus BASE CURRENT



COLLECTOR CURRENT versus EMITTER BASE VOLTAGE



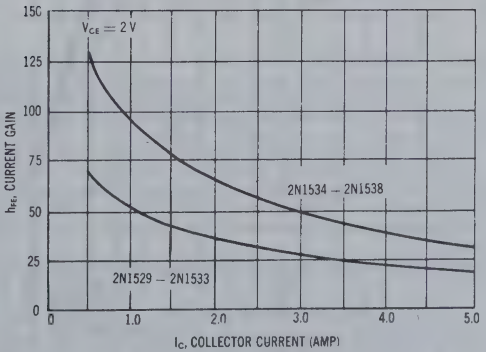
SWITCHING TIME MEASURING CIRCUIT



TYPICAL SWITCHING CHARACTERISTICS

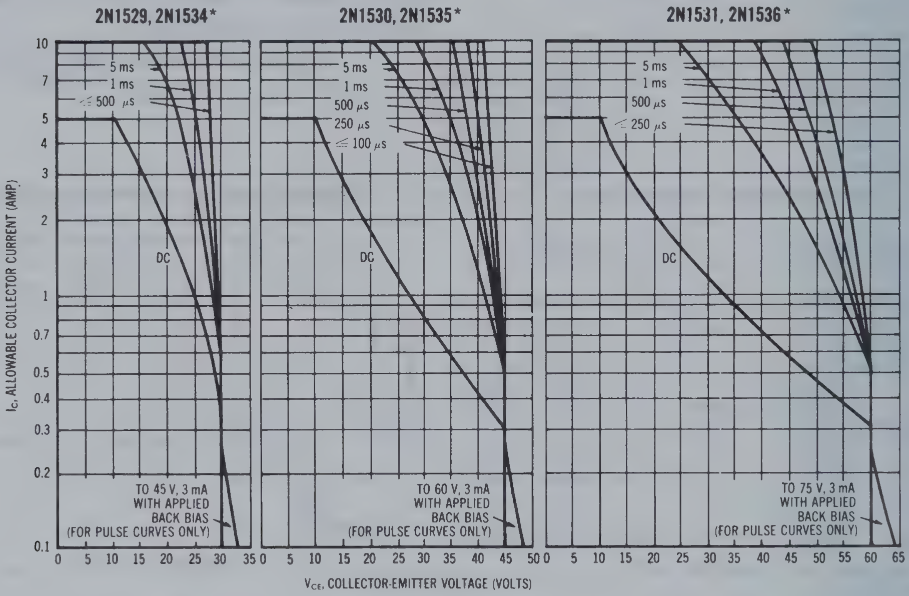
	I_C (AMP)	V (VOLTS)	R (ohms)	$t_d + t_r$ (μs)	t_s (μs)	t_f (μs)
2N1529-33	3	3	65	10	2	5
2N1534-38	3	3	100	8	3	5

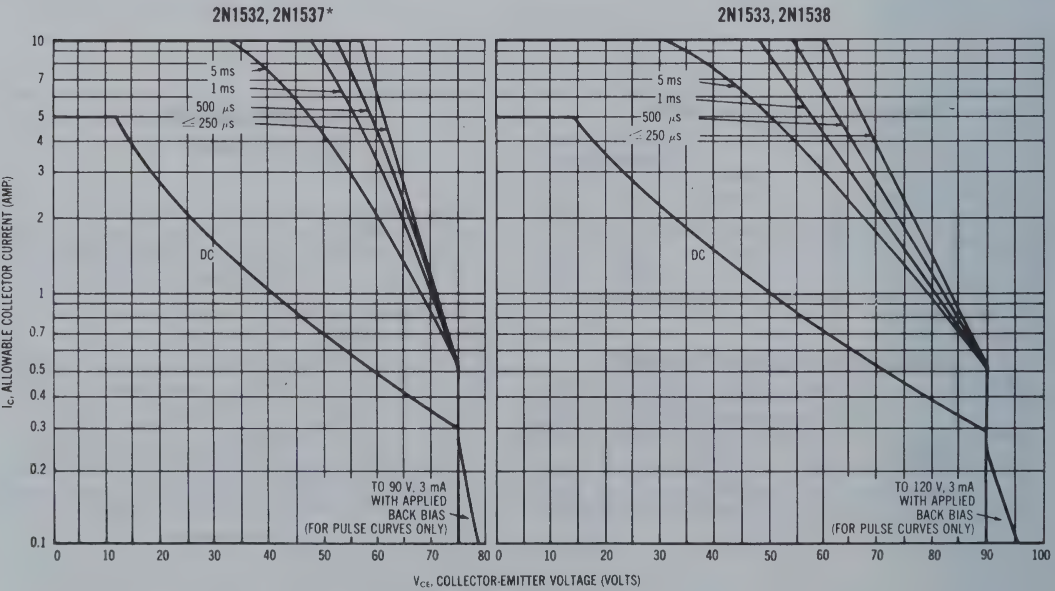
DC CURRENT GAIN versus COLLECTOR CURRENT



SAFE OPERATING AREAS — PULSE CONDITIONS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.



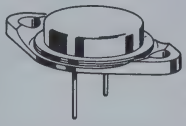


*Characteristics apply to corresponding "A" type numbers also.

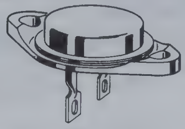
2N1539 thru 2N1548 (GERMANIUM)

2N1539A thru 2N1542A, 2N1544A thru 2N1547A

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP1539, A etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N1539 2N1544	2N1540 2N1545	2N1541 2N1546	2N1542 2N1547	2N1543 2N1548	Unit
Collector-Emitter Voltage	V_{CEO}	20	30	40	50	60	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	120	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	50	60	Vdc
Collector Current-Continuous	I_C	5.0					Adc
Peak	I_C	10					Adc
Total Device Dissipation @T_C = 25° C	P_D	106					Watts
Operating Junction Temperature Range	T_J	-65 to +110					°C

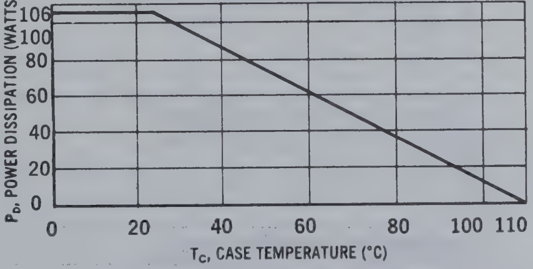
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For d. c. or frequencies below 25 cps the transistor must be operated within the constant $P_D = Vc \times Ic$ hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25^{O}C and is 0 Watts at 110^{O}C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^{O} - Tc}{0.8}$$

POWER-TEMPERATURE DERATING CURVE



2N1539 thru 2N1548 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

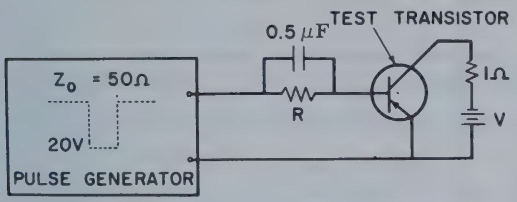
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage‡		BV_{CEO}‡			volts
(I_C = 500 mAdc, I_B = 0)	2N1539, 2N1544		20	-	
	2N1540, 2N1545		30	-	
	2N1541, 2N1546		40	-	
	2N1542, 2N1547		50	-	
	2N1543, 2N1548		60	-	
Collector-Emitter Breakdown Voltage‡		BV_{CES}‡			volts
(I_C = 500 mAdc, V_{BE} = 0)	2N1539, 2N1544		30	-	
	2N1540, 2N1545		45	-	
	2N1541, 2N1546		60	-	
	2N1542, 2N1547		75	-	
	2N1543, 2N1548		90	-	
Collector-Base Breakdown Voltage		BV_{CBO}			volts
(I_C = 20 mAdc, I_E = 0)	2N1539, 2N1544		40	-	
	2N1540, 2N1545		60	-	
	2N1541, 2N1546		80	-	
	2N1542, 2N1547		100	-	
	2N1543, 2N1548		120	-	
Collector Cutoff Current (V_{CE} @ rated V_{CB}, V_{BE} = 1.0 Vdc)		I_{CEX}	-	20	mA
Collector Cutoff Current		I_{CBO}			mA
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.2	
(V_{CB} = 1/2 V_{CES} rating, T_C = 90°C)			-	20	
Collector Cutoff Current		I_{CBO1}			mA
(V_{CB} = 25 Vdc, I_E = 0)	2N1539, 2N1544		-	2.0	
(V_{CB} = 40 Vdc, I_E = 0)	2N1540, 2N1545		-	2.0	
(V_{CB} = 55 Vdc, I_E = 0)	2N1541, 2N1546		-	2.0	
(V_{CB} = 65 Vdc, I_E = 0)	2N1542, 2N1547		-	2.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N1543, 2N1548		-	2.0	
ON CHARACTERISTICS					
DC Current Gain		h_{FE1}			-
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N1539-2N1543		50	100	
	2N1544-2N1548		75	150	
DC Transconductance		g_{FE}			mhos
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N1539-2N1543		3.0	-	
	2N1544-2N1548		5.0	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			volts
(I_C = 3.0 Adc, I_B = 300 mAdc)	2N1539-2N1543		-	0.3	
	2N1544-2N1548		-	0.2	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			volts
(I_C = 3.0 Adc, I_B = 300 mAdc)	2N1539-2N1543		-	0.7	
	2N1544-2N1548		-	0.5	
DYNAMIC CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		$f_{\alpha e}$	Typ 4.0		kHz

Characteristics apply to corresponding A type numbers also.

‡To avoid excessive heating of collector junction, perform this test with a sweep method.

2N1539 thru 2N1548 (continued)

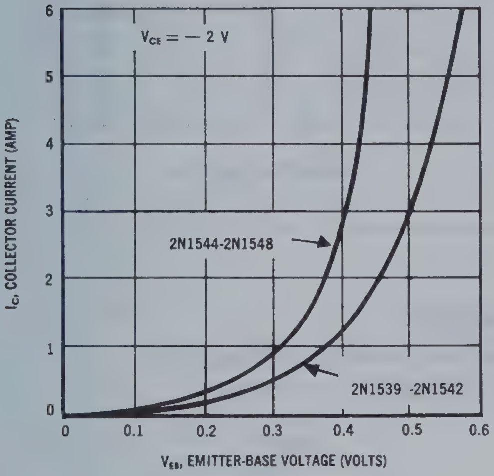
SWITCHING TIME MEASURING UNIT



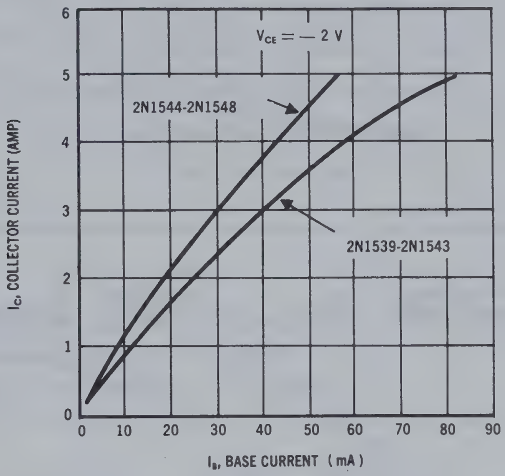
Devices	Conditions*			Typical Switching Times		
	I_C (Amp)	V (Volts)	R (ohms)	$t_d + t_r$ (μs)	t_s (μs)	t_f (μs)
2N1539-43	3	3	165	5	3	5
2N1544-48	3	3	250	5	3	8

*Input Pulse Repetition Rate = 2 kHz,
Pulse Width = 50 μs

COLLECTOR CURRENT versus EMITTER BASE VOLTAGE



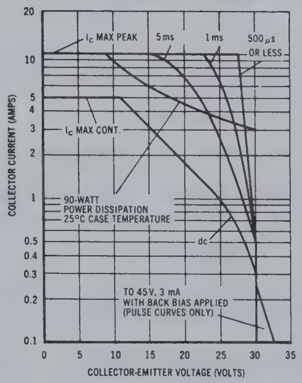
COLLECTOR CURRENT versus BASE CURRENT



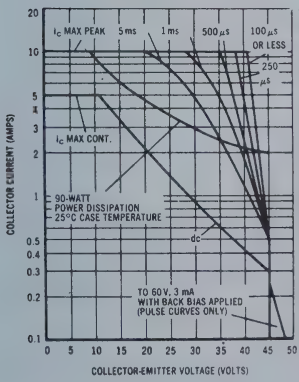
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

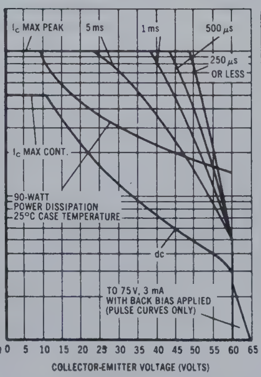
2N1539, 2N1544



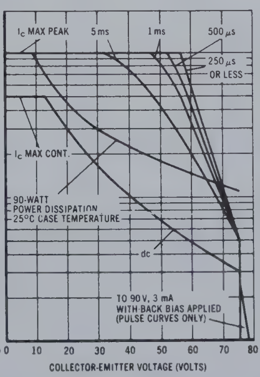
2N1540, 2N1545



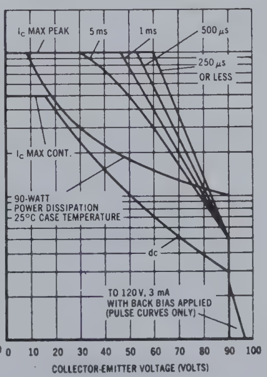
2N1541, 2N1546



2N1542, 2N1547

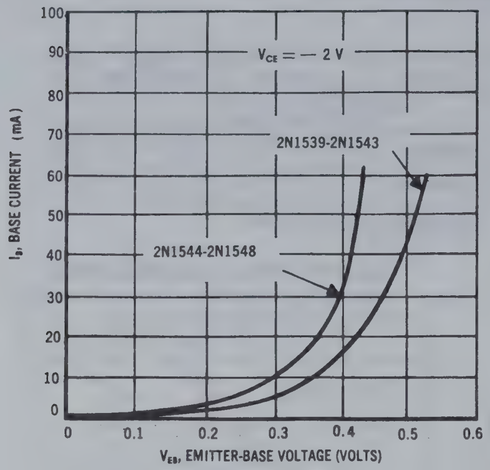


2N1543, 2N1548

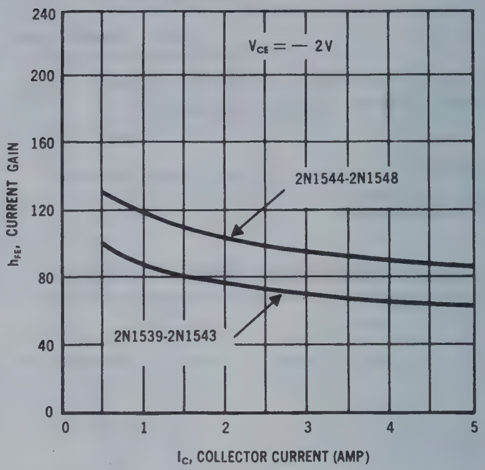


2N1539 thru 2N1548 (continued)

BASE CURRENT versus EMITTER BASE VOLTAGE

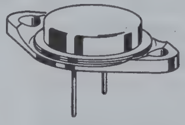


DC CURRENT GAIN versus COLLECTOR CURRENT



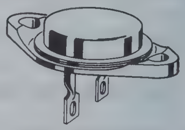
2N1549, A thru 2N1560, A (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.



CASE 11A
(TO-3 modified)

For units with solder lugs attached, specify devices MP1549, A etc. (TO-41 package)



CASE 4-04
(TO-41)

MAXIMUM RATINGS Apply to corresponding "Hi-Rel" Series also

Rating	Symbol	2N1549 2N1553 2N1557	2N1550 2N1554 2N1558	2N1551 2N1555 2N1559	2N1552 2N1556 2N1560	Units
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	Vdc
Collector-Emitter Voltage	V_{CES}*	30	45	60	75	Vdc
Collector-Emitter Voltage	V_{CEO}*	20	30	40	50	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	50	Vdc
Collector Current (Continuous)	I_C	15				Amp
Collector Current (Peak)	I_C	20				Amp
Collector Junction Temperature	T_J	-65 to +110				°C
Collector Dissipation (25°C Case Temp.)	P_D	106				Watts
Thermal Resistance	θ_{JC}	0.8				°C/W

*To avoid excessive heating of collector junction, perform this test with a sweep method.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics apply to corresponding A type numbers also.

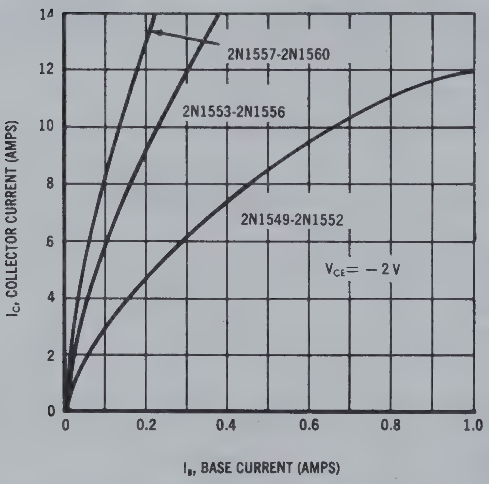
Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO1}			mA
(V_{CB} = 25 V)	2N1549, 2N1553, 2N1557		-	3.0	
(V_{CB} = 40 V)	2N1550, 2N1554, 2N1558		-	3.0	
(V_{CB} = 55 V)	2N1551, 2N1555, 2N1559		-	3.0	
(V_{CB} = 65 V)	2N1552, 2N1556, 2N1560		-	3.0	
Collector-Base Cutoff Current		I_{CBO}			mA
(V_{CB} = 2 V)			-	0.2	
(V_{CB} = 1/2 BV_{CES} rating; T_C = +90° C)			-	20	
Emitter-Base Cutoff Current (V_{EB} = 12 V)		I_{EBO}	-	0.5	mA
Collector-Emitter Breakdown Voltage (I_C = 300 mA)		BV_{CES}			volts
	2N1549, 2N1553, 2N1557		30	-	
	2N1550, 2N1554, 2N1558		45	-	
	2N1551, 2N1555, 2N1559		60	-	
	2N1552, 2N1556, 2N1560		75	-	
Collector-Emitter Leakage Current (V_{BE} = 1.0 V, V_{CE} @ rated BV_{CBO})		I_{CEX}	-	20	mA
Collector-Emitter Breakdown Voltage* (I_C = 300 mA, I_B = 0)		BV_{CEO}*			volts
	2N1549, 2N1553, 2N1557		20	-	
	2N1550, 2N1554, 2N1558		30	-	
	2N1551, 2N1555, 2N1559		40	-	
	2N1552, 2N1556, 2N1560		50	-	
Collector-Base Breakdown Voltage (I_C = 20 mA)		BV_{CBO}			volts
	2N1549, 2N1553, 2N1557		40	-	
	2N1550, 2N1554, 2N1558		60	-	
	2N1551, 2N1555, 2N1559		80	-	
	2N1552, 2N1556, 2N1560		100	-	
Current Gain (V_{CE} = 2.0 V, I_C = 10 A)		h_{FE1}			-
	2N1549 - 2N1552		10	30	
	2N1553 - 2N1556		30	60	
	2N1557 - 2N1560		50	100	
Base-Emitter Drive Voltage (I_C = 10 A, I_B = 1.0 A)		V_{BE}			volts
	2N1549 - 2N1552		-	1.3	
	2N1553 - 2N1556		-	1.0	
	2N1557 - 2N1560		-	0.85	
Collector Saturation Voltage (I_C = 10 A, I_B = 1.0 A)		$V_{CE(sat)}$			volts
	2N1549 - 2N1552		-	1.0	
	2N1553 - 2N1556		-	0.7	
	2N1557 - 2N1560		-	0.5	

*To avoid excessive heating of collector junction, perform this test with a sweep method.

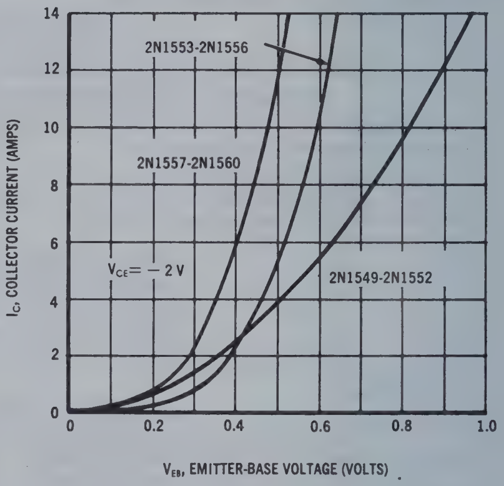
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
Transconductance (V_{CE} = 2.0 V, I_C = 10 A)	g_{FE}			mhos
2N1549 - 2N1552		6.0	18	
2N1553 - 2N1556		8.0	30	
2N1557 - 2N1560		12	40	
Frequency Cutoff	f_{ae}	Typ		kHz
2N1549 - 2N1552		10		
2N1553 - 2N1556		6.0		
2N1557 - 2N1560		5.0		

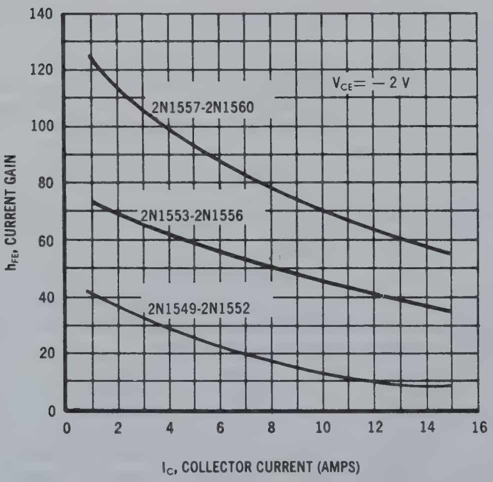
COLLECTOR CURRENT versus BASE CURRENT



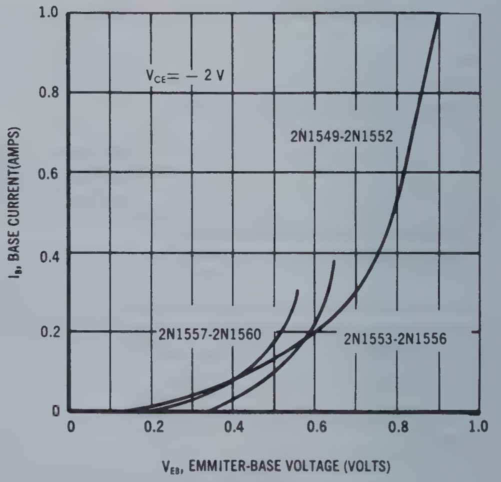
COLLECTOR CURRENT versus EMITTER-BASE VOLTAGE



CURRENT GAIN versus COLLECTOR CURRENT



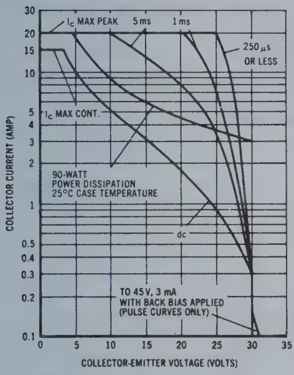
BASE CURRENT versus EMITTER-BASE VOLTAGE



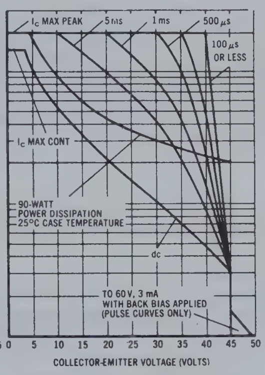
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

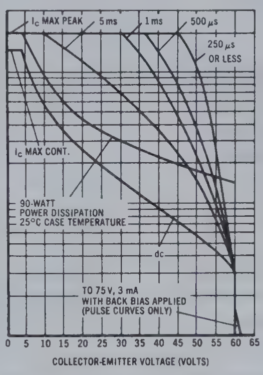
2N1549, 2N1553, 2N1557



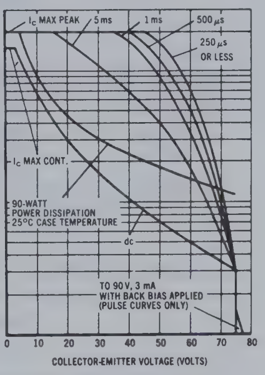
2N1550, 2N1554, 2N1558



2N1551, 2N1555, 2N1559

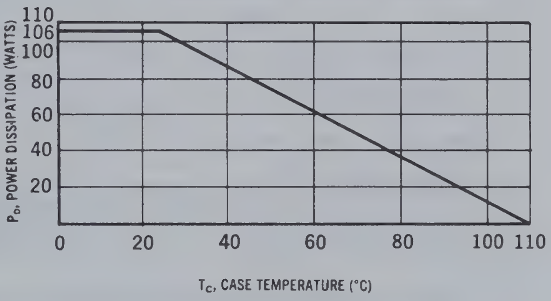


2N1552, 2N1556, 2N1560

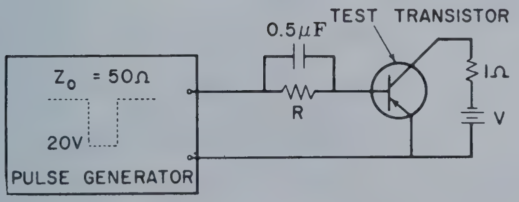


POWER-TEMPERATURE DERATING CURVE

The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For dc or frequencies below 25 Hz the transistor must be operated within the constant $P_D = V_C \times I_C$ hyperbolic curve. This curve has a value of 106 watts at case temperatures of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that P_D allowable $= \frac{110^\circ - T_C}{0.8}$



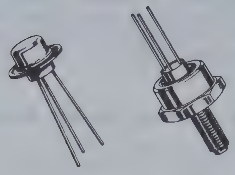
SWITCHING TIME MEASURING UNIT



Devices	Conditions*			Typical Switching Times		
	I_C (Amp)	V (Volts)	R (ohms)	$t_d + t_r$ (μs)	t_s (μs)	t_f (μs)
2N1549 -52	10	10	10	5	2	10
2N1553 -56	10	10	30	10	5	25
2N1557 -60	10	10	50	10	5	25

* Input Pulse Repetition Rate = 2 kHz,
Pulse Width = 50 μs

2N1561 (GERMANIUM)
2N1562
2N1692
2N1693



PNP germanium mesa transistors for VHF power amplifier applications.

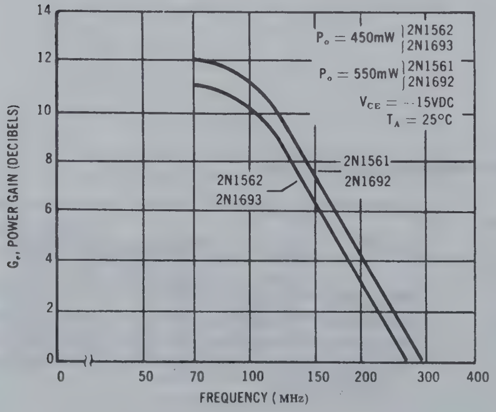
CASE 23	**CASE 24**
(TO-107)	(TO-102)
2N1561 2N1562	2N1692 2N1693

Collector connected to case;
stud isolated from case

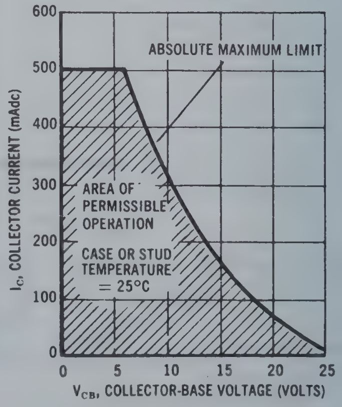
MAXIMUM RATINGS

Rating	Symbol	2N1561	2N1562	2N1692	2N1693	Unit
Collector-Emitter Voltage	V_{CE}	25	25	25	25	Vdc
Collector-Base Voltage	V_{CB}	25	25	25	25	Vdc
Emitter-Base Voltage*	V_{EB}*	3.0	2.0	3.0	2.0	Vdc
Collector Current-Continuous Peak	I_C	250 500	250 500	250 500	250 500	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	250 3.33	250 3.33	350 4.67	350 4.67	mW $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	3.0 40	3.0 40	3.0 40	3.0 40	Watts $mW/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to 100				^oC

*May be exceeded provided total rated device dissipation is not exceeded.



POWER GAIN versus FREQUENCY

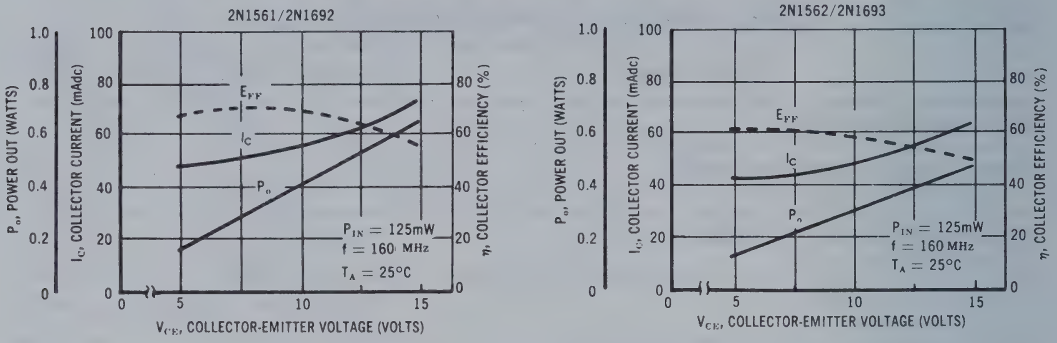


SAFE OPERATING AREA

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

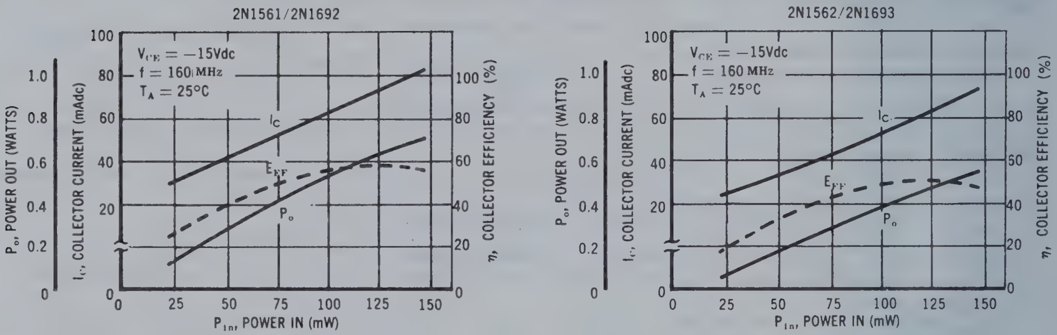
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	25	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	-	Adc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	1.5	10	μAdc
Emitter Cutoff Current	I_{EBO}				mAdc
(V_{BE} = 0.4 Vdc, I_C = 0) 2N1562, 2N1693		-	5.0	-	
(V_{BE} = 1.0 Vdc, I_C = 0) 2N1561, 2N1692		-	5.0	-	
ON CHARACTERISTICS					
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 200 mAdc, I_B = 40 mAdc) 2N1561, 2N1692		-	-	3.0	
(I_C = 200 mAdc, I_B = 40 mAdc) 2N1562, 2N1693		-	-	4.0	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product	f_T				MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N1561, 2N1692		-	500	-	
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N1562, 2N1693		-	450	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	7.0	10	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 160 MHz) 2N1561, 2N1692	h_{fe}	-	10	-	dB
2N1562, 2N1693		-	9.0	-	
Extrinsic Base Resistance (I_E = 20 mAdc, V_{CB} = 10 Vdc, f = 300 MHz)	r'_b	-	25	-	Ohms
FUNCTIONAL TEST					
Power Gain	G_{pe}				dB
(I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{out} = 0.5 W, f = 160 MHz) 2N1561, 2N1692		6.0	-	-	
(I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{out} = 0.4 W, f = 160 MHz) 2N1562, 2N1693		5.0	-	-	
Power Output (I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{in} = 125 mW, f = 160 MHz)	P_{out}				Watt
2N1561, 2N1692		0.5	-	-	
2N1562, 2N1693		0.4	-	-	

POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus COLLECTOR-EMITTER VOLTAGE


2N1561/2N1692

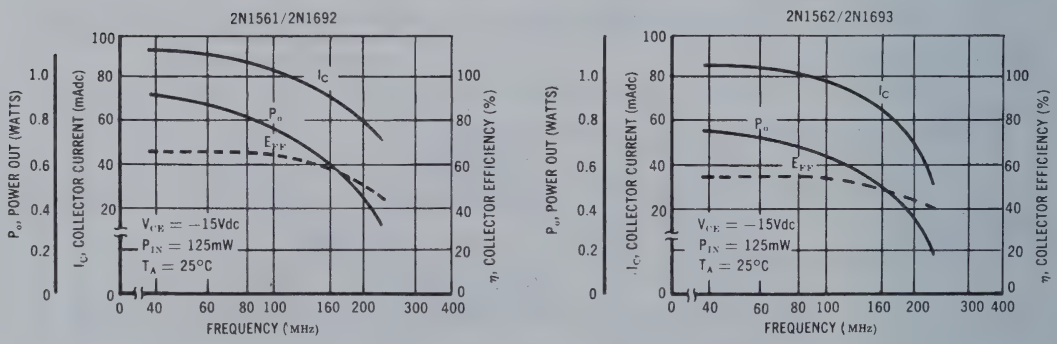
2N1562/2N1693

POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus POWER IN


2N1561/2N1692

2N1562/2N1693

POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus FREQUENCY


2N1561/2N1692

2N1562/2N1693

2N1595 thru 2N1599 (SILICON)

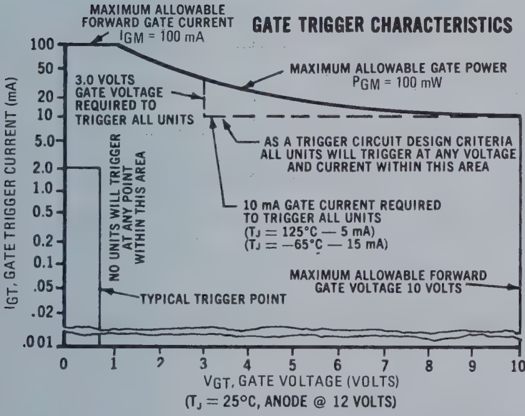
CASE 31(2)
(TO-5)

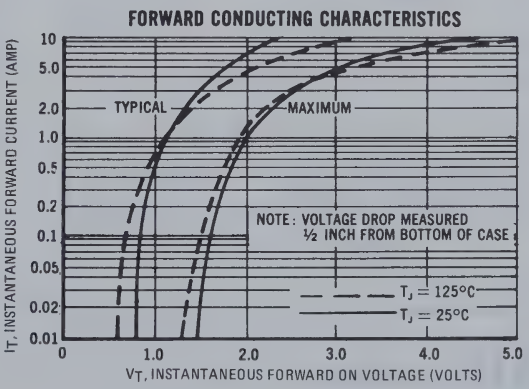
Industrial-type, low-current silicon controlled rectifiers in a three-lead package ideal for printed-circuit applications. Current handling capability of 1.6 amperes at junction temperatures to 125°C.

MAXIMUM RATINGS (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{RSM(rep)}$*		Volts
2N1595		50	
2N1596		100	
2N1597		200	
2N1598		300	
2N1599		400	
Forward Current RMS (All Conduction Angles)	$I_{T(RMS)}$	1.6	Amp
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)	I_{TSM}	15	Amp
Peak Gate Power - Forward	P_{GM}	0.1	Watt
Average Gate Power - Forward	$P_{G(AV)}$	0.01	Watt
Peak Gate Current - Forward	I_{GM}	0.1	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	10	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*V_{RSM} for all types can be applied on a continuous dc basis without incurring damage.





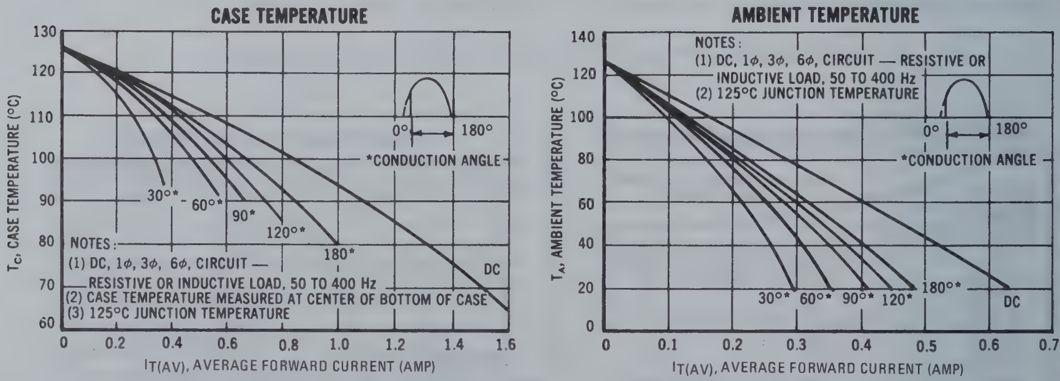
2N1595 thru 2N1599 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 125°C)	V_{DRM}*				Volts
2N1595		50	—	—	
2N1596		100	—	—	
2N1597		200	—	—	
2N1598		300	—	—	
2N1599		400	—	—	
Peak Forward Blocking Current (Rated V_{DRM} with gate open, T_J = 125°C)	I_{DRM}	—	—	1.0	mA
Peak Reverse Blocking Current (Rated V_{RSM}, T_J = 125°C)	I_{RRM}	—	—	1.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 12 Ω)	I_{GT}	—	2.0	10.0	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 12 Ω)	V_{GT}	—	0.7	3.0	Volts
(V_{DRM} = Rated, R_L = 12 Ω, T_J = 125°C)	V_{GNT}	0.2	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_H	—	5.0	—	mA
Forward On Voltage (I_T = 1 Adc)	V_{TM}	—	1.1	2.0	Volts
Turn-On Time ($t_d + t_r$) (I_{GT} = 10 mA, I_T = 1A)	t_{gt}	—	0.8	—	μs
Turn-Off Time (I_T = 1 A, I_R = 1 A, dv/dt = 20 V/μs, T_J = 125°C) (V_{DRM} = rated voltage)	t_q	—	10	—	μs

*V_{DRM} for all types can be applied on a continuous dc basis without incurring damage.

CURRENT DERATING

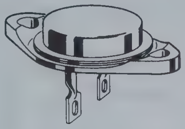


2N1613 (SILICON)

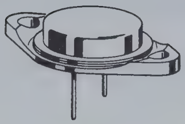
For Specifications, See 2N718A Data.

2N1651 thru 2N1653 (Germanium)

2N2285 thru 2N2287 (Germanium)



CASE 161
(TO-41)
2N1651 thru 2N1653
Collector connected to case



CASE 3A
(TO-3 modified)
2N2285 thru 2N2287

PNP Germanium power transistors designed for high-current switching applications requiring low saturation voltages and fast switching times in addition to good safe operating area.

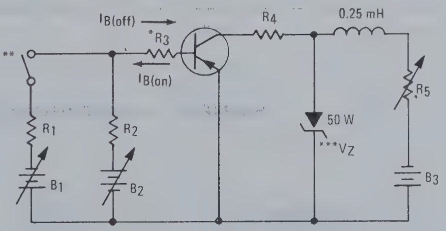
MAXIMUM RATINGS

Rating	Symbol	2N1651 2N2285	2N1652 2N2286	2N1653 2N2287	Unit
Collector-Emitter Voltage	V_{CEO}	30	60	80	Vdc
Collector-Base Voltage	V_{CB}	60	100	120	Vdc
Emitter-Base Voltage	V_{EB}	←	1.5	→	Vdc
Collector Current - Continuous	I_C	←	25	→	Adc
Base Current - Continuous	I_B	←	5.0	→	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	←	106 1.25	→	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +110	→	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

FIGURE 1 — SUSTAINING VOLTAGE TEST CIRCUIT



R_1 = 1.0 Ohm, 20 Watts
R_2 = 7.5 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 1.5 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc

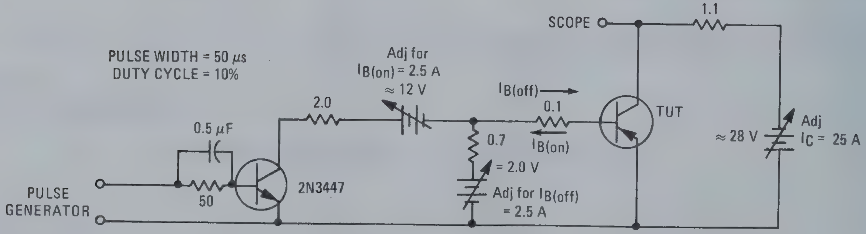
*Not required if current probe is used to read I_{B1}
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum.

2N1651 thru 2N1653/2N2285 thru 2N2287 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N1651, 2N2285	BV_{CEO}	30	-	Vdc
	2N1652, 2N2286		60	-	
	2N1653, 2N2287		80	-	
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 25 Adc)	2N1651, 2N2285	$V_{CE(sus)}$	40	-	Vdc
	2N1652, 2N2286		45	-	
	2N1653, 2N2287		50	-	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO1}	-	200	μAdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	2N1651, 2N2285	I_{CBO2}	-	5.0	mAdc
(V_{CB} = 80 Vdc, I_E = 0)	2N1652, 2N2286		-	5.0	
(V_{CB} = 100 Vdc, I_E = 0)	2N1653, 2N2287		-	5.0	
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C)	2N1651, 2N2285	I_{CBO3}	-	35	mAdc
(V_{CB} = 80 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C)	2N1652, 2N2286		-	35	
(V_{CB} = 100 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C)	2N1653, 2N2287		-	35	
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	2N1651, 2N2285	I_{CBO4}	-	20	mAdc
(V_{CB} = 100 Vdc, I_E = 0)	2N1652, 2N2286		-	20	
(V_{CB} = 120 Vdc, I_E = 0)	2N1653, 2N2287		-	20	
Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)		I_{EBO}	-	50	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	35	140	-
(I_C = 25 Adc, V_{CE} = 1.5 Vdc)			20	-	
Collector-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{CE(sat)}$	-	0.30	Vdc
Base-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{BE(sat)}$	-	0.65	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)		h_{fe}	20	-	-
SWITCHING CHARACTERISTICS					
Rise Time	(I_C = 25 Adc, $I_{B(on)}$ = 2.5 Adc, $I_{B(off)}$ = 2.5 Adc) (See Figure 2)	t_r	-	12	μs
Storage Time		t_s	-	10	μs
Fall Time		t_f	-	8.0	μs

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N1692, 2N1693

For Specifications, See 2N1561 Data.

2N1705 thru 2N1707 (GERMANIUM)

PNP germanium transistors for audio driver applications in transistorized radio receivers.

CASE 31(1)
(TO-5)

Base connected to case

MAXIMUM RATINGS

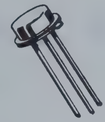
Rating	Symbol	2N1705	2N1706	2N1707	Unit
Collector-Base Voltage	V_{CB}	18	25	30	Vdc
Collector-Emitter Voltage (R_{BE} = 1 K)	V_{CER}	12	18	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	10	Vdc
Collector Current	I_C	400			mA
Collector Dissipation at T_C = 25°C	P_D	200			mW
Junction Temperature Range	T_J	-65 to +100			°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				µAdc
(V_{CB} = -10 Vdc)	2N1705		---	5.0	10	
	2N1706		---	---	10	
(V_{CB} = -25 Vdc)	2N1707		---	---	15	
Emitter-Base Cutoff Current		I_{EBO}				µAdc
(V_{EB} = -5 Vdc)	2N1705		---	4.0	20	
	2N1706		---	---	20	
(V_{EB} = -10 Vdc)	2N1707		---	---	10	
Collector-Emitter Voltage		BV_{CER}				Vdc
(I_C = 1 mAdc, R_{BE} = 1 K)	2N1705		12	---	---	
	2N1706		18	---	---	
	2N1707		25	---	---	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 10 mA, V_{CE} = 5 V)	2N1706		0.15	---	0.35	
(I_C = 20 mA, V_{CE} = 1 V)	2N1705		0.2	---	0.4	
DC Current Gain		h_{FE}				---
(I_C = 10 mAdc, V_{CE} = -5 V)	2N1707		40	90	150	
(I_C = 20 mAdc, V_{CE} = -1 V)	2N1706		60	---	120	
Small Signal Current Gain		h_{fe}				---
(I_C = 1 mA, V_{CE} = -6 V, f = 1 kHz)	2N1705		70	110	150	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706		50	90	150	
	2N1707		30	---	150	
Output Admittance Conductance		h_{ob}				µmhos
(I_C = 1 mA, V_{CB} = -6 V, f = 1 kHz)	2N1705		---	0.5	---	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706, 2N1707		---	3.0	---	
Input Impedance		h_{ib}				ohms
(I_C = 1 mA, V_{CE} = -6 V, f = 1 kHz)	2N1705		---	30	---	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706, 2N1707		---	4.0	---	
Voltage Feedback Ratio						
(I_C = 1 mA, V_{CB} = -6 V, f = 1 kHz)	2N1705	h_{rb}	---	3.0	---	$X10^{-4}$
(I_C = 10 mA, V_C = -5 V, f = 1 kHz)	2N1706	h_{re}	---	0.69	---	$X10^{-3}$
	2N1707	h_{rb}	---	4.5	---	$X10^{-4}$
Frequency Cutoff		$f_{\alpha b}$				MHz
(I_C = 1 mA, V_C = -6 V)	2N1706, 2N1707		---	3.0	---	
	2N1705		---	4.0	---	
Output Capacitance		C_{ob}				pF
(I_C = 1 mA, V_{CB} = -6 V, f = 1 MHz)			---	20	---	
Noise Figure		NF				dB
(I_C = 1 mA, V_{CB} = -6 V, R_s = 1 K, f = 1 kHz)	2N1705		---	6.0	---	

2N1708 (SILICON)

CASE 26
(TO-46)



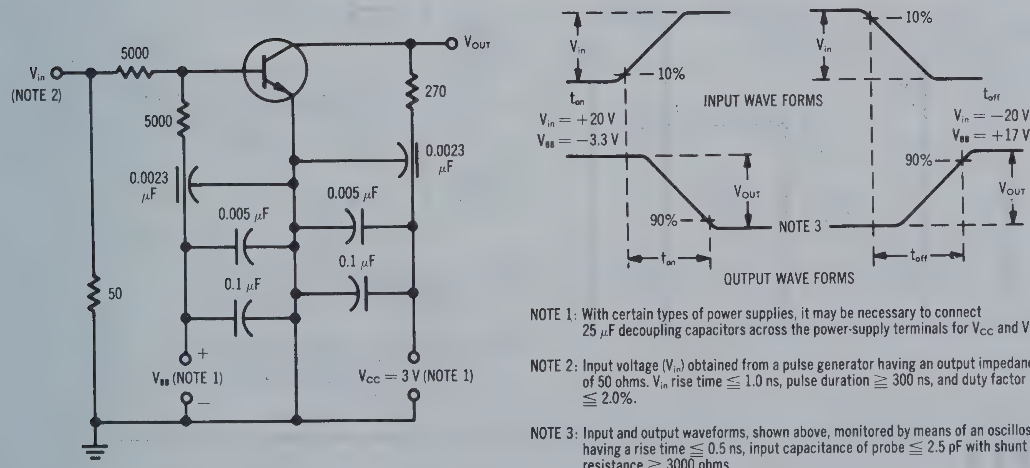
Collector electrically connected to case

NPN silicon transistor designed for very high-speed, low-power saturated switching applications for computers in military and industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.0 6.67	Watt mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


V_in (NOTE 2)
5000
5000
0.0023 µF
50
0.005 µF
0.1 µF
V_BB (NOTE 1)
+
−
V_OUT
270
0.0023 µF
0.005 µF
0.1 µF
V_CC = 3 V (NOTE 1)
V_in
10%
t_on
V_in = +20 V
V_BB = −3.3 V
INPUT WAVE FORMS
V_in
10%
t_off
V_in = −20 V
V_BB = +17 V
90%
V_OUT
NOTE 3
t_on
90%
V_OUT
t_off
OUTPUT WAVE FORMS

NOTE 1: With certain types of power supplies, it may be necessary to connect 25 µF decoupling capacitors across the power-supply terminals for V_{CC} and V_{BB}.

NOTE 2: Input voltage (V_{in}) obtained from a pulse generator having an output impedance of 50 ohms. V_{in} rise time $\leq$ 1.0 ns, pulse duration $\geq$ 300 ns, and duty factor $\leq$ 2.0%.

NOTE 3: Input and output waveforms, shown above, monitored by means of an oscilloscope having a rise time $\leq$ 0.5 ns, input capacitance of probe $\leq$ 2.5 pF with shunt resistance $\geq$ 3000 ohms.

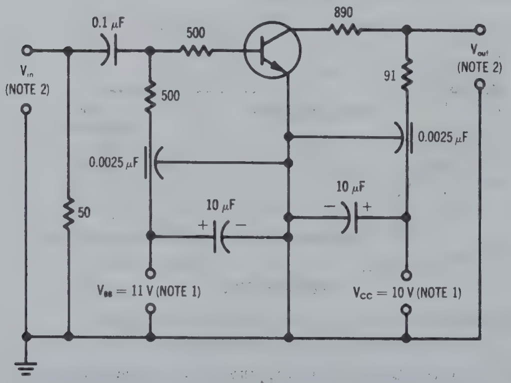
2N1708 (continued)

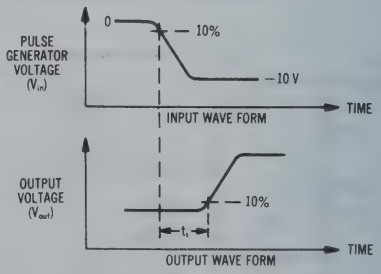
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	12	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector-Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.25 Vdc, T_A = 100°C)	I_{CEX}	-	15	μAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.025 15	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	20	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	- -	0.22 0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.7	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	6.0	pF
Turn-On Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{on}	-	40	ns
Turn-Off Time (Figure 1) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	75	ns
Storage Time (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	-	25	ns

* Pulse Test: Pulse Length ≤ 6.0 ms, Duty Cycle ≤ 30%.

FIGURE 2 — STORAGE TIME TEST CIRCUIT


0.1 μF
500
890
V_{in} (NOTE 2)
500
91
V_{out} (NOTE 2)
0.0025 μF
0.0025 μF
10 μF
10 μF
50
V_{BB} = 11 V (NOTE 1)
V_{CC} = 10 V (NOTE 1)


PULSE GENERATOR VOLTAGE (V_{in})
0
10%
−10 V
TIME
INPUT WAVE FORM
OUTPUT VOLTAGE (V_{out})
10%
t_s
OUTPUT WAVE FORM
TIME

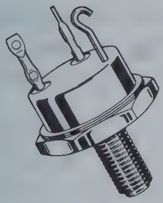
NOTE 1: Input voltage (V_{in}) obtained from pulse generator having an output impedance of 50 ohms. V_{in} rise time < 1 ns, pulse duration ≥ 300 ns, and duty factor ≤ 2.0%.

NOTE 2: Input and output wave forms monitored by means of an oscilloscope having a rise time ≤ 0.5 ns; input capacitance of probe ≤ 2.5 pF with shunt resistance ≥ 1000 ohms.

2N1711

For Specifications, See 2N718A Data.

2N1724 (SILICON)
2N1725



CASE 9
(TO-61)

NPN silicon power transistors designed for switching and amplifier applications.

MAXIMUM RATINGS

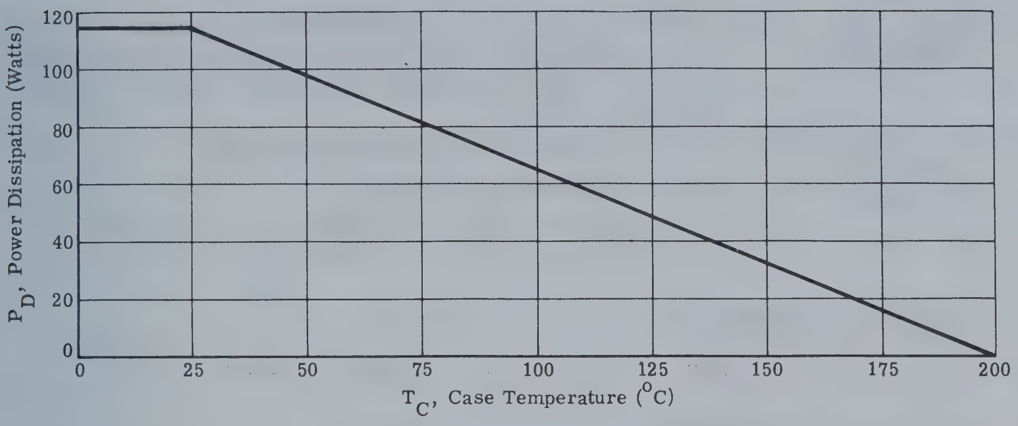
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	120	Vdc
Collector-Emitter Voltage	V_{CE}	80	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Collector Current (Continuous)	I_C	5.0	Adc
Power Dissipation	P_D	117	Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5	°C/W
Junction Operating Temperature Range	T_J	-65 to +200	°C

2N1724, 2N1725 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Emitter-Base Cutoff Current	I_{EBO}				mAdc
(V_{EB} = 9 Vdc) 2N1725		-	-	0.5	
(V_{EB} = 10 Vdc)		-	-	10.0	
Collector-Emitter Cutoff Current	I_{CES}				mAdc
(V_{CE} = 60 Vdc, V_{BE} = 0)		-	-	1.0	
(V_{CE} = 60 Vdc, V_{BE} = 0, T_C = 150°C)		-	-	2.0	
(V_{CE} = 120 Vdc, V_{BE} = 0, T_C = 150°C)		-	-	10.0	
Collector-Base Cutoff Current (V_{CB} = 3 Vdc, I_E = 0)	I_{CBO}	-	-	0.1	mAdc
Collector-Emitter Sustaining Voltage (I_C = 200 mAdc, I_B = 0)	$V_{CEO(sus)}$	80	-	-	Vdc
DC Current Gain	h_{FE}				
(V_{CE} = 15 Vdc, I_C = 2 Adc) 2N1724		20	40	90	
2N1725		50	90	150	
(V_{CE} = 15 Vdc, I_C = 2 Adc, T_A = -55°C) 2N1724		12	-	-	
2N1725		25	-	-	
(V_{CE} = 15 Vdc, I_C = 0.1 Adc) 2N1724		20	-	-	
2N1725		50	-	-	
Collector-Emitter Saturation Voltage (I_C = 2 Adc, I_B = 200 mAdc)	$V_{CE(sat)}$		0.5	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 2 Adc, I_B = 200 mAdc)	$V_{BE(sat)}$		1.2	2.0	Vdc
High Frequency Current Gain (V_{CE} = 15 Vdc, I_C = 0.5 Adc, f = 10 MHz)	h_{fe}	1.0	1.6	-	
Common Base Output Capacitance (V_{CB} = 10 Vdc, f = 0.1 MHz)	C_{ob}		260	550	pF
Switching Times (I_C = 2 Adc, I_{B1} = $-I_{B2}$ = 0.2 Adc)					μs
Delay time plus Rise time	$t_d + t_r$	-	0.15	-	
Storage time	t_s	-	1.3	-	
Fall time	t_f		0.14		

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



SAFE OPERATING AREAS

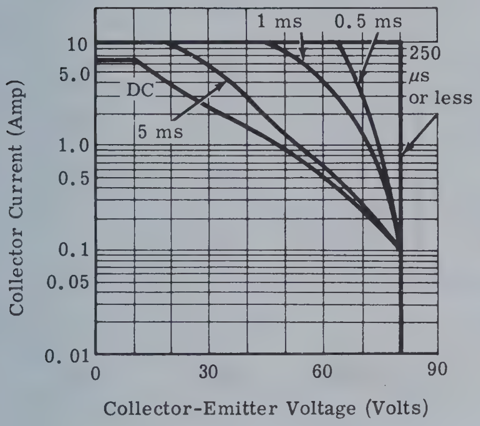
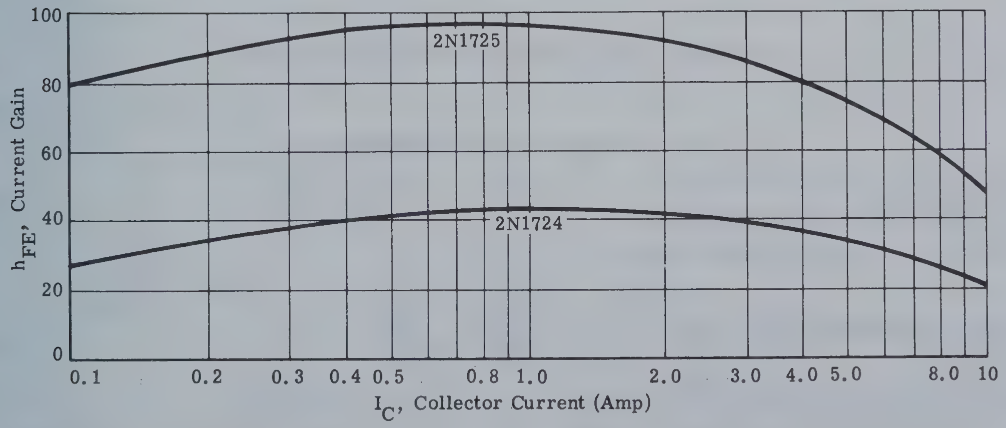


FIGURE 2 — 2N1724, 2N1725

In using these curves the average power derating curve (Fig. 1) must be observed to ensure operation below the maximum junction temperature.

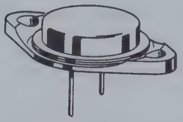
FIGURE 3 — DC CURRENT GAIN versus COLLECTOR CURRENT



2N1742

For Specifications, See 2N499 Data.

2N1751 (GERMANIUM)



Collector Connected to Case

CASE 3A
(TO-3 modified)

PNP Germanium power transistor designed for high-current switching applications requiring low saturation voltages, short switching times and good sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.3 Vdc (Max) @ I_C = 20 Adc
  $V_{BE(sat)}$ = 0.7 Vdc (Max) @ I_C = 20 Adc

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
*Collector-Base Voltage	V_{CB}	80	Vdc
*Emitter-Base Voltage	V_{EB}	2.5	Vdc
*Collector Current - Continuous	I_C	25	Adc
Base Current - Continuous	I_B	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	106 1.25	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

THERMAL CHARACTERISTICS

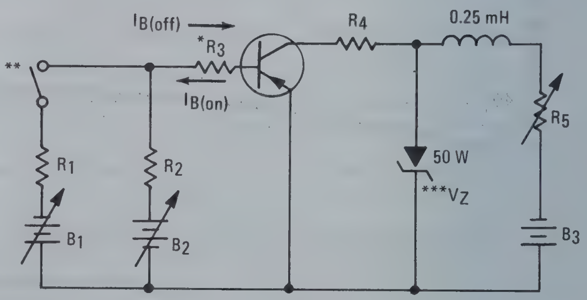
Characteristic	Symbol	Max	Unit
*Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

* Indicates JEDEC Registered Data.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT

R_1 = 1.0 Ohm, 20 Watts
R_2 = 10 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 2.0 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc



*Not required if current probe is used to read I_B
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum.
Adjust input pulse width for I_C = 25 A condition.

2N1751 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

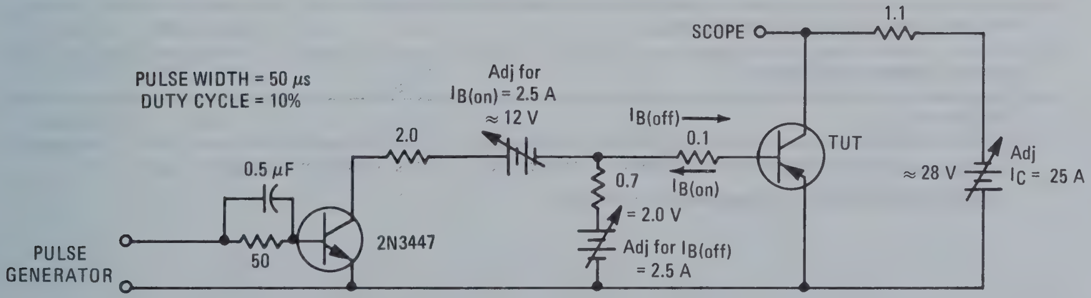
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	60	-	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 25 Adc)	$V_{CE(sus)}$	45	-	Vdc
*Floating Potential (V_{CB} = 80 Vdc, I_E = 0)	V_{EBF}	-	1.0	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 80 Vdc, R_{BE} = 50 Ohms)	I_{CER}	-	50	mAdc
Collector Cutoff Current (V_{CE} = 80 Vdc, V_{BE} = 0)	I_{CES}	-	5.0	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO1}	-	200	µAdc
Collector Cutoff Current *(V_{CB} = 80 Vdc, I_E = 0) (V_{CB} = 80 Vdc, I_E = 0, T_C = 100°C, +0, -3°C)	I_{CBO2}	- -	5.0 25	mAdc
*Emitter Cutoff Current (V_{EB} = 2.5 Vdc, I_C = 0)	I_{EBO}	-	50	mAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 20 Adc, V_{CE} = 1.5 Vdc)	h_{FE}	30	90	-
Collector-Emitter Saturation Voltage (I_C = 20 Adc, I_B = 2.5 Adc)	$V_{CE(sat)}$	-	0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 20 Adc, I_B = 2.5 Adc)	$V_{BE(sat)}$	-	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Common-Base Cutoff Frequency (I_C = 0.5 Adc, V_{CB} = 10 Vdc)	$f_{\alpha b}$	1.5	-	MHz
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)	h_{fe}	20	-	-

SWITCHING CHARACTERISTICS

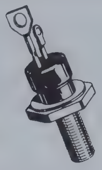
Characteristic	Conditions	Symbol	Min	Max	Unit
Rise Time	(I_C = 25 Adc, $I_{B(on)}$ = 2.5 Adc, $I_{B(off)}$ = 2.5 Adc) (See Figure 2)	t_r	-	12	µs
Storage Time		t_s	-	10	µs
Fall Time		t_f	-	8.0	µs

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT


SCOPE
1.1
PULSE WIDTH = 50 µs
DUTY CYCLE = 10%
Adj for
$I_{B(on)}$ = 2.5 A
≈ 12 V
$I_{B(off)}$
2.0
0.1
TUT
0.5 µF
0.7
$I_{B(on)}$
≈ 28 V
Adj
I_C = 25 A
= 2.0 V
Adj for $I_{B(off)}$
= 2.5 A
PULSE
GENERATOR
50
2N3447

2N1842 thru 2N1850 (SILICON)



CASE 263

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 16 amperes at junction temperatures to 100°C. MCR equivalents available in TO-48 package – i.e. – 2N1842 available in TO-48 package as MCR1842.

MAXIMUM RATINGS ($T_J = 100°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{RSM(rep)}$*		Volts
2N1842		25	
2N1843		50	
2N1844		100	
2N1845		150	
2N1846		200	
2N1847		250	
2N1848		300	
2N1849		400	
2N1850		500	
Peak Reverse Blocking Voltage	$V_{RSM(non\text{-}rep)}$		Volts
(Transient) 2N1842		35	
(Non-Recurrent 5 ms max.) 2N1843		75	
2N1844		150	
2N1845		225	
2N1846		300	
2N1847		350	
2N1848		400	
2N1849		500	
2N1850		600	
Forward Current RMS (All Conduction Angles)	$I_{T(RMS)}$	16	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C, t ≦ 8.3 ms)	I^2t	60	A^2s
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -40 to +100°C)	I_{TSM}	125	Amp
Peak Gate Power -	P_{GM}	5.0	Watts
Average Gate Power	$P_{G(AV)}$	0.5	Watt
Peak Gate Current -	I_{GM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +125	°C
Stud Torque	—	30	in. lb.

*$V_{RSM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage.

Ratings apply for zero or negative gate voltage.

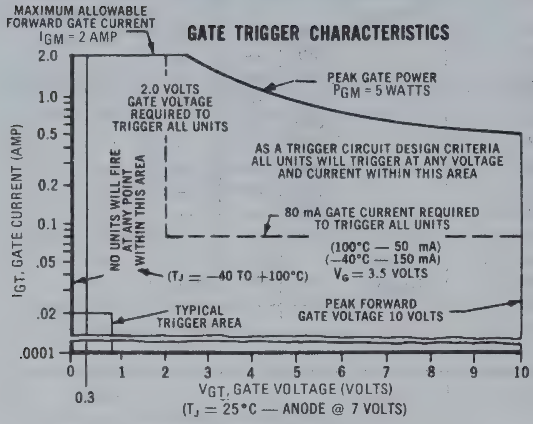
2N1842 thru 2N1850 (continued)

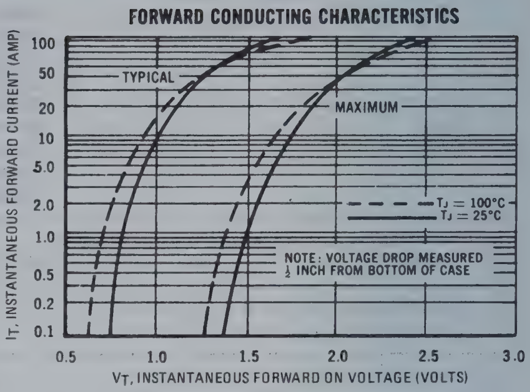
ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

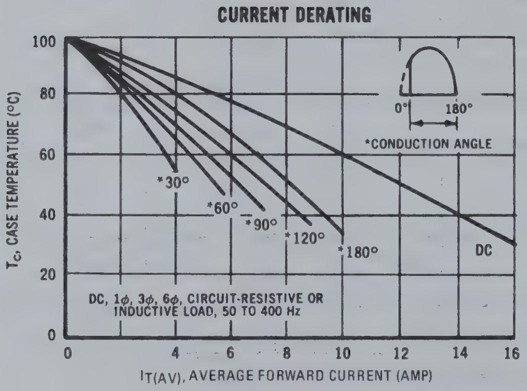
Characteristic		Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 100°C)	2N1842	V_{DRM}*	25	—	—	Volts
	2N1843		50	—	—	
	2N1844		100	—	—	
	2N1845		150	—	—	
	2N1846		200	—	—	
	2N1847		250	—	—	
	2N1848		300	—	—	
	2N1849		400	—	—	
	2N1850		500	—	—	
Peak Forward or Reverse Blocking Current (Rated V_{FOM} or V_{ROM} gate open, T_J = 100°C)		I_{DRM} I_{RRM}	—	—	6.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		I_{GT}	—	15	80	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		V_{GT}	—	0.8	2.0	Volts
(V_{DRM} = Rated V, R_L = 50 Ω, T_J = 100°C)		V_{GNT}	0.3	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)		I_H	—	20	—	mA
Forward On Voltage (I_F = 16 Adc)		V_{TM}	—	1.1	1.8	Volts
Turn-On Time ($t_d + t_r$) (I_G = 50 mA, I_F = 10 A)		t_{gt}	—	1.0	—	μs
Turn-Off Time (I_F = 10 A, I_R = 10 A; dv/dt = 20 V/μs, T_J = 100°C) (V_{DRM} = rated voltage)		t_q	—	25	—	μs
Forward Voltage Application Rate (Gate open, T_J = 100°C)		dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)		θ_{JC}	—	1.0	2.0	°C/W

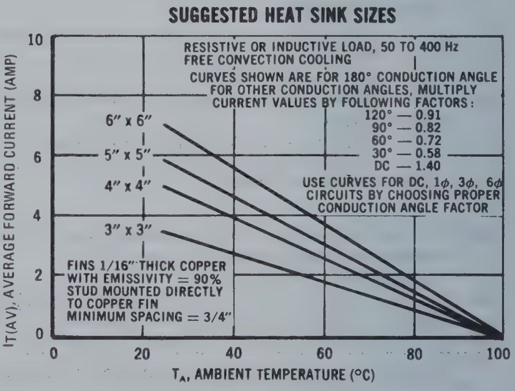
*V_{DRM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative voltage.

2N1842 thru 2N1850 (continued)

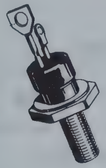

GATE TRIGGER CHARACTERISTICS


FORWARD CONDUCTING CHARACTERISTICS


CURRENT DERATING


SUGGESTED HEAT SINK SIZES

2N1842A thru 2N1850A (SILICON)



CASE 263

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 16 amperes at junction temperatures to 125°C.

MAXIMUM RATINGS ($T_J = 125°C$ unless otherwise noted)

Rating		Symbol	Value	Unit
Peak Reverse Blocking Voltage*		$V_{RSM(rep)}$*		Volts
	2N1842A		25	
	2N1843A		50	
	2N1844A		100	
	2N1845A		150	
	2N1846A		200	
	2N1847A		250	
	2N1848A		300	
	2N1849A		400	
	2N1850A		500	
Peak Reverse Blocking Voltage (Transient) (Non-Recurrent 5 ms max.)		$V_{RSM(non-rep)}$		Volts
	2N1842A		35	
	2N1843A		75	
	2N1844A		150	
	2N1845A		225	
	2N1846A		300	
	2N1847A		350	
	2N1848A		400	
	2N1849A		500	
	2N1850A		600	
Forward Current RMS		$I_{T(RMS)}$	16	Amp
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)		I_{TSM}	125	Amp
Circuit Fusing Considerations (T_J = -65 to +125°C, t ≦ 8.3 ms)		I^2t	60	A^2s
Peak Gate Power - Forward		P_{GM}	5.0	Watts
Average Gate Power - Forward		$P_{G(AV)}$	0.5	Watt
Peak Gate Current - Forward		I_{GM}	2.0	Amp
Peak Gate Voltage - Forward		V_{GFM}	10	Volts
Reverse		V_{GRM}	5.0	
Operating Junction Temperature Range		T_J	-65 to +125	°C
Storage Temperature Range		T_{stg}	-65 to +150	°C
Stud Torque		—	30	in. lb.

*$V_{RSM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage.

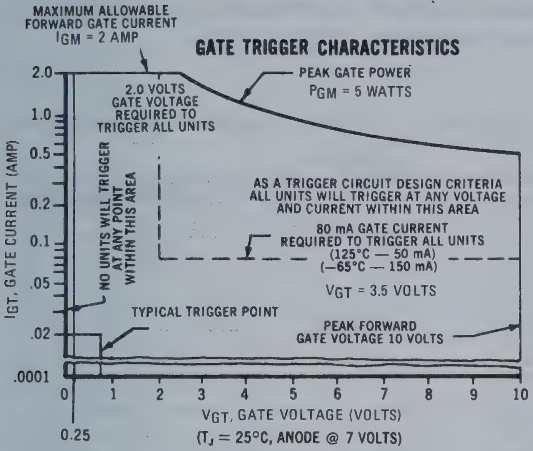
Ratings apply for zero or negative gate voltage.

2N1842 A thru 2N1850A (continued)

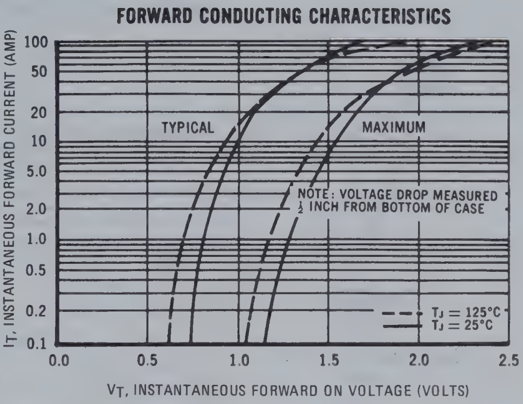
ELECTRICAL CHARACTERISTICS (T_c = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 125°C)		V_{DRM}*				Volts
	2N1842A		25	—	—	
	2N1843A		50	—	—	
	2N1844A		100	—	—	
	2N1845A		150	—	—	
	2N1846A		200	—	—	
	2N1847A		250	—	—	
	2N1848A		300	—	—	
	2N1849A		400	—	—	
	2N1850A		500	—	—	
Peak Forward or Reverse Blocking Current (V_{DRM}, OR V_{RSM}, gate open, T_J = 125°C)		I_{DRM} I_{RRM}	—	—	6.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		I_{GT}	—	15	80	mA
Gate Trigger Voltage (Anode Voltage = 7 Vdc, R_L = 50 Ω)		V_{GT}	—	0.8	2.0	Volts
(V_{DRM} = Rated V, R_L = 50 Ω, T_J = 125°C)		V_{GNT}	0.25	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)		I_H	—	20	—	mA
Forward On Voltage (I_T = 16 Adc)		V_T	—	1.1	1.6	Volts
Turn-On Time (t_d + t_r) (I_{GT}= 50 mA, I_T = 10 A)		t_{gt}	—	1.0	—	μs
Turn-Off Time (I_T = 10 A, I_R = 10 A, dv/dt = 20 V/μs, T_J = 125°C)		t_q	—	30	—	μs
Forward Voltage Application Rate (Gate Open, T_J = 125°C)		dv/dt	—	30	—	V/ μs
Thermal Resistance (Junction to Case)		θ_{JC}	—	1.0	2.0	°C/W

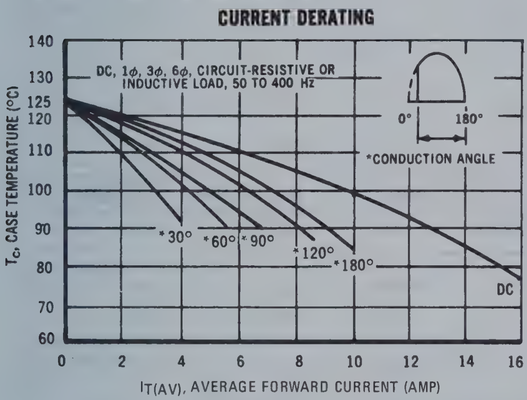
*V_{DRM} for all types can be applied on a continuous dc basis without incurring damage.
Ratings apply for zero or negative gate voltage.



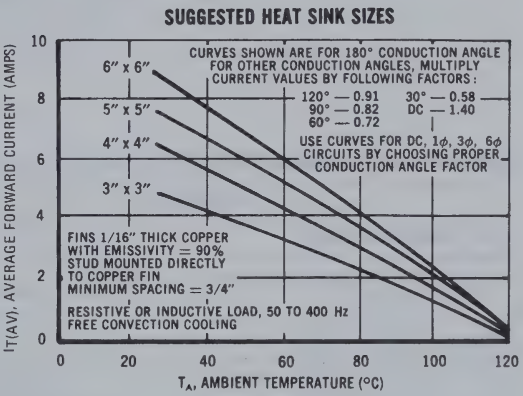
GATE TRIGGER CHARACTERISTICS



FORWARD CONDUCTING CHARACTERISTICS



CURRENT DERATING



SUGGESTED HEAT SINK SIZES

2N1893 (SILICON)
2N2405

NPN silicon annular transistors designed for medium-power amplifier and switching applications.

CASE 31
(TO-5)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N1893	2N2405	Unit
Collector-Emitter Voltage	V_{CEO}	80	90	Vdc
Collector-Emitter Voltage	V_{CER}	100	140	Vdc
Collector-Base Voltage	V_{CB}	120		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	0.5	1.0	Adc
Total Device Dissipation @ T_A = 25°C	P_D	0.8	1.0	Watt
Derate above 25°C		4.57	5.71	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	3.0	5.0	Watts
Derate above 25°C		17.2	28.6	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	2N1893	2N2405	Unit
Thermal Resistance, Junction to Case	θ_{JC}	58.3	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	219	175	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

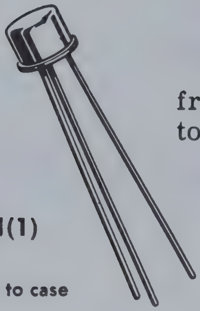
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
(I_C = 30 mAdc, I_B = 0)	2N1893		80	-	
(I_C = 100 mAdc, I_B = 0)	2N2405		90	-	
Collector-Emitter Sustaining Voltage		$BV_{CER(sus)}$			Vdc
(I_C = 100 mAdc, R_{BE} = 10 ohms)	2N1893		100	-	
	2N2405		140	-	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	120	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 90 Vdc, I_E = 0)			-	0.01	
(V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	2N1893		-	15	
	2N2405		-	10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	0.01	μAdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain [1]		h_{FE}			-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N1893		20	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N1893		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N1893		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N1893		40	120	
	2N2405		60	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N1893		-	1.2	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N1893		-	5.0	
	2N2405		-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N1893		-	0.9	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N1893		-	1.3	
	2N2405		-	1.1	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N1893		50	-	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, 100 kHz ≦ f ≦ 1.0 MHz)			-	15	
Input Capacitance		C_{ib}			pF
(V_{BE} = 0.5 Vdc, I_C = 0, 100 kHz ≦ f ≦ 1.0 MHz)	2N1893		-	85	
Input Impedance		h_{ib}			ohms
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		20	30	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893, 2N2405		4.0	8.0	
Voltage Feedback Ratio		h_{rb}			X 10^{-4}
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		-	1.25	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893		-	1.5	
	2N2405		-	3.0	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1893		30	100	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2405		50	275	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1893		45	-	
Output Admittance		h_{ob}			μmho
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		-	0.5	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893, 2N2405		-	0.5	

[1] Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N1924 thru 2N1926 (GERMANIUM)



CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for general purpose, low-frequency applications. Characteristics curves similar to 2N524-2N527 series.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	25	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J & T_{stg}	-65 to +100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (TC = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -45 Vdc, I_E = 0	I_{CBO}	–	10	μAdc
Emitter Cutoff Current V_{EB} = -25 Vdc, I_C = 0	I_{EBO}	–	10	μAdc
Collector-Base Voltage I_C = 200 μAdc, I_E = 0	V_{CBO}	60	–	Vdc
Collector-Emitter Voltage I_C = 50 μAdc, V_{BE} = +1.5 Vdc, R_{BE} = 10 K	V_{CEX}	50	–	Vdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	V_{CER}	40	–	Vdc
Punch-Thru Voltage (V_{EB} = 1 Vdc, VTVM Z $\geq$ 1 Megohm)	V_{pt}	50	–	Vdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristics	Symbol	Min	Max	Unit
DC Current Gain I_C = 20 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N1924		34	65	–
2N1925		53	90	
2N1926		72	121	
DC Current Gain I_C = 100 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N1924		30	–	–
2N1925		47	–	
2N1926		65	–	
Collector-Emitter Saturation Voltage	$V_{CE(SAT)}$			
I_B = 1.33 mAdc, I_C = 20 mAdc 2N1924		50	110	mVdc
I_B = 1.0 mAdc, I_C = 20 mAdc 2N1925		55	110	
I_B = 0.67 mAdc, I_C = 20 mAdc 2N1926		60	110	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}			
2N1924		200	300	mVdc
2N1925		190	290	
2N1926		180	280	
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	–	30	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			
2N1924		1.0	–	MHz
2N1925		1.3	–	
2N1926		1.5	–	
Small-Signal Short-Circuit Forward-Transfer Current Ratio V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{fe}			
2N1924		30	64	–
2N1925		44	88	
2N1926		60	120	
Small-Signal Open Circuit Output Admittance V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{oe}			
2N1924		15	60	μmho
2N1925		20	65	
2N1926		25	70	
Small-Signal Open-Circuit Reverse-Transfer Voltage Ratio V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{re}			
2N1924		2.0	8.0	$X10^{-4}$
2N1925		3.0	9.0	
2N1926		4.0	10	
Small-Signal Short-Circuit Input Impedance V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ie}			
2N1924		700	2200	ohms
2N1925		1200	3200	
2N1926		1500	4200	

2N1959 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

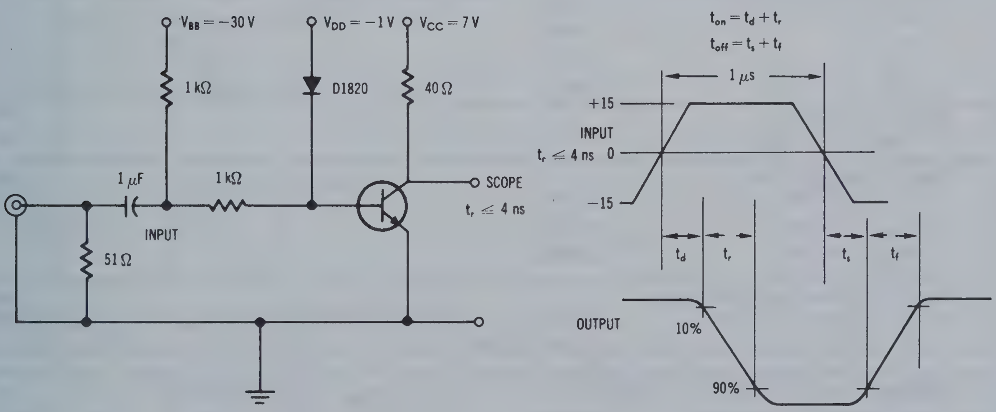
Rating	Symbol	Value	Unit
Collector-Emitter Voltage R_{BE} = 10 ohms	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	600 4.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.0 1.3	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 50 μAdc, R_{BE} = 10 ohms)		BV_{CER}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	 — —	 0.5 300	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 150 mAdc, V_{CE} = 10 Vdc)		h_{FE}	40	120	—
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	—	0.45	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE\,(sat)}$	—	1.3	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 25 mAdc, V_{CB} = 10 Vdc, f = 100 MHz)		f_T	100	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	18	pF
Turn-On Time	Figure 1 (V_{CC} = 7 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc,	t_{on}	—	65	ns
Turn-Off Time		t_{off}	—	45	ns
Storage Time		t_s	—	25	ns

*t_{on}, t_{off}, and t_s measured from 50% point of input pulse.

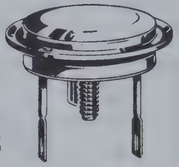
FIGURE 1 — SWITCHING TIME TEST CIRCUIT



V_{BB} = −30 V
1 kΩ
V_{DD} = −1 V
D1820
V_{CC} = 7 V
40 Ω
1 μF
1 kΩ
INPUT
51 Ω
SCOPE
t_r ≤ 4 ns
$t_{on} = t_d + t_r$
$t_{off} = t_s + t_f$
1 μs
+15
INPUT
t_r ≤ 4 ns
0
−15
t_d
t_r
t_s
t_f
OUTPUT
10%
90%

2N1970 (GERMANIUM)

2N1980 thru 2N1982



CASE 5
(TO-36)

PNP germanium power transistors for general purpose amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N1970	2N1980	2N1981	2N1982	Unit
Collector-Base Voltage	V_{CB}	100	50	70	90	Volts
Collector-Emitter Voltage	V_{CEO}	50	30	40	50	Volts
Emitter-Base Voltage	V_{EB}	40	20	20	20	Volts
Collector Current	I_C	15				Amp
Power Dissipation at $T_C = 25^{\circ}C$	P_D	170				Watts
Junction Temperature Range	T_J	-65 to +110				°C

ELECTRICAL CHARACTERISTICS ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = -100 Vdc)	2N1970		—	4.0	
(V_{CB} = -50 Vdc)	2N1980		—	6.0	
(V_{CB} = -70 Vdc)	2N1981		—	6.0	
(V_{CB} = -90 Vdc)	2N1982		—	6.0	
(V_{CB} = -2 Vdc)	2N1980-2N1982		—	0.3	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = -40 Vdc)	2N1970		—	4.0	
(V_{EB} = -20 Vdc)	2N1980-2N1982		—	5.0	
(V_{EB} = -2 Vdc)	2N1980-2N1982		—	0.3	
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 1 Adc, I_B = 0)	2N1970		50	—	
	2N1980		30	—	
	2N1981		40	—	
	2N1982		50	—	
Base-Emitter Voltage		V_{BE}			Vdc
(V_{CE} = -2 Vdc, I_C = 5 Adc)	2N1970		—	0.9	
Emitter Floating Potential		V_{EBF}			Vdc
(V_{CB} = -50 Vdc)	2N1980		—	1.0	
(V_{CB} = -70 Vdc)	2N1981		—	1.0	
(V_{CB} = -90 Vdc)	2N1982		—	1.0	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 12 Adc, I_B = 2 Adc)	2N1970		—	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N1980-2N1982		—	0.5	
DC Current Gain		h_{FE}			—
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N1970		17	40	
	2N1980-2N1982		50	100	
(I_C = 12 Adc, V_{CE} = -2 Vdc)	2N1970		10	—	
Common Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(V_{CE} = -4 V, I_C = 5 A)	2N1970		5.0	—	
(V_{CE} = -5 V, I_C = 2 A)	2N1980-2N1982		3.0	—	

2N1983 (SILICON)
2N1984

CASE 31
(TO-5)
Collector connected to case

NPN silicon annular small-signal transistor.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	0.6 4.8	Watt mW/° C
Total Device Dissipation @ T_C = 25° C Derate above 25° C	P_D	2.0 16	Watts mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	° C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	62.5	° C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	208	° C/W

2N1983, 2N1984 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage [1] (I_C = 100 mAdc, I_B = 0)	$BV_{CEO(sus)}$	25	-	Vdc
Collector-Emitter Sustaining Voltage [1] (I_C = 100 mAdc, $R_{BE} \leqq$ 10 ohms)	$BV_{CER(sus)}$	30	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	5.0 200	μAdc
Emitter-Cutoff Current ($V_{EB(off)}$ = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter On Voltage (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	-	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	40	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	45	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc) 2N1983 2N1984	h_{ie}	- -	2.0 1.2	k ohm
Input Resistance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20 4.0	30 8.0	ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983 2N1984 (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983 2N1984	h_{rb}	- - - -	7.0 5.0 7.0 5.0	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983 2N1984 (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983 2N1984	h_{fe}	70 35 80 40	210 100 240 120	-
Output Admittance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc) 2N1983 2N1984	h_{oe}	- -	200 100	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	- -	1.0 1.5	μmho

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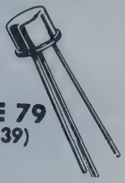
[1] Pulse Test: Pulse Width $\leqq$ 300 μs, Duty Cycle $\leqq$ 2.0%.

2N1990 (SILICON)



CASE 79
(TO-39)

Collector connected to case

NPN silicon transistor designed for driving neon display tubes.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current-Continuous	I_C	1.0	Adc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	0.6 4.8	W mW/°C
Total Device Dissipation $T_C = 2.5°C$ @ $T_C = 100°C$	P_D	2.0 1.0	W
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	62.5	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	208	°C/W

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector Cutoff Current	I_{CEX}			
($V_{CE} = 75$ Vdc, $I_B = 10$ μAdc)		-	10	μAdc
($V_{CE} = 75$ Vdc, $I_B = 250$ μAdc, $T_A = 150°C$		-	250	
ON CHARACTERISTICS				
DC Current Gain ($I_C = 30$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	20	-	-
Collector-Emitter Saturation Voltage ($I_C = 2.0$ mAdc, $I_B = 0.2$ mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Saturation Voltage ($I_C = 2.0$ mAdc, $I_B = 0.2$ mAdc)	$V_{BE(sat)}$	-	1.0	Vdc

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2N1991 (SILICON)

For Specifications, See 2N1131 Data.

2N2042, 2N2043 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads
isolated from case

PNP germanium transistors suitable for high-voltage audio switching and amplifier applications. Suitable for high-reliability projects.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	105	Vdc
Collector-Emitter Voltage	V_{CES}	105	Vdc
Emitter-Base Voltage	V_{EB}	75	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Operating Junction Temperature Range	T_J	-65 to +100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C
Collector Dissipation, Ambient Derate above 25°C	P_D	200 2.67	mW mW/°C
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

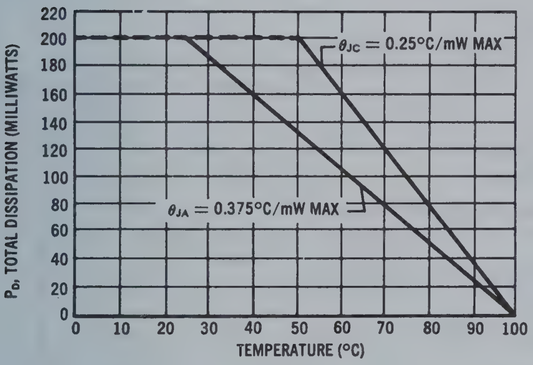
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 105 V, I_E = 0)		–	25	
(V_{CB} = 2.5 V, I_E = 0)		–	10	
(V_{CB} = 105 V, I_E = 0, T_A = +71°C)		–	500	
Emitter-Base Cutoff Current	I_{EBO}			μAdc
(V_{EB} = 75 V, I_C = 0)		–	50	
(V_{EB} = 2.5 V, I_C = 0)		–	10	
Collector-Emitter Cutoff Current	I_{CER}			μAdc
(V_{CE} = 55 V, R_{BE} = 10 K)		–	600	
Collector-Emitter Cutoff Current	I_{CES}			mAdc
(V_{CE} = 105 V, V_{BE} = 0)		–	1.0	
DC Collector-Emitter Punch-Through Voltage	V_{pt}			Vdc
(V_{f1} = 1.0 V, VTVM R_{in} 10-12 megohm)		105	–	
DC Current Gain	h_{FE}			–
(I_C = 5 mA, V_{CE} = 0.35 V) 2N2042 2N2043		20 40	50 100	
Common Base, Small-Signal Input Impedance	h_{ib}			Ohms
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)		30	50	

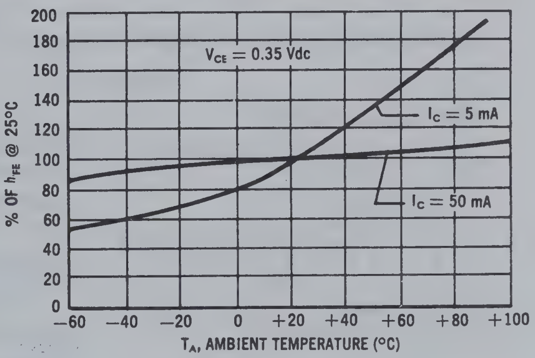
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
Common Base, Small-Signal Output Admittance (V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)	h_{ob}	0.1	1.0	μmho
Common Emitter, Small-Signal Current Transfer Ratio (V_{CE} = 6 V, I_C = 1 mA, f = 1 kHz) 2N2042	h_{fe}	20	80	–
2N2043		45	180	
Base-Emitter Saturation Voltage (I_C = 5 mA, I_B = 0.25 mA)	$V_{BE(sat)}$	–	0.30	Vdc
Collector-Emitter Saturation Voltage (I_C = 5 mA, I_B = 0.25 mA)	$V_{CE(sat)}$	–	0.25	Vdc
(I_C = 100 mA, I_B = 10 mA)		–	0.75	
Collector Output Capacitance (V_{CB} = 6 V, I_E = 0)	C_{ob}	–	25	pF
Common-Base, Small-Signal Forward Current Transfer Ratio Cutoff Frequency (V_{CB} = 6 V, I_E = 1 mA) 2N2042	$f_{\alpha b}$	0.50	–	MHz
2N2043		0.75	–	

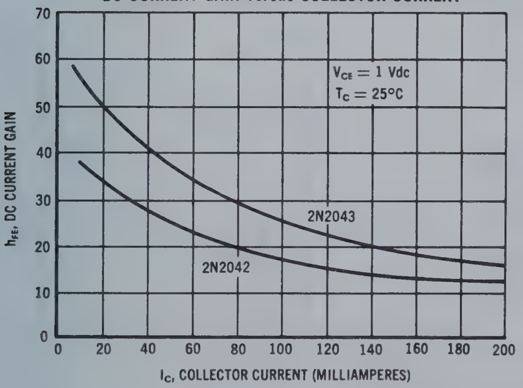
POWER-TEMPERATURE DERATING CURVE



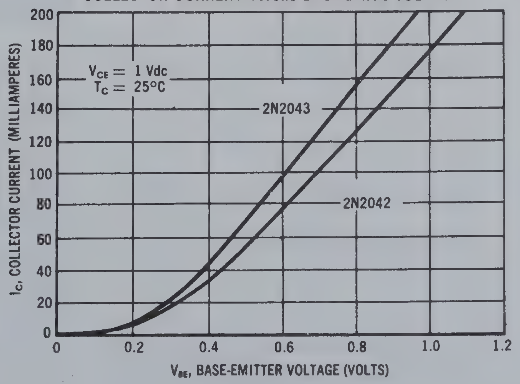
LARGE SIGNAL CURRENT GAIN versus TEMPERATURE



DC CURRENT GAIN versus COLLECTOR CURRENT



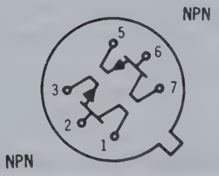
COLLECTOR CURRENT versus BASE-DRIVE VOLTAGE



2N2060, A (SILICON)
2N2060 JAN, JTX AVAILABLE
2N2223, A
2N2480, A

NPN silicon annular Star dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.

Case 654-04
TO-78



PINS 4 AND 8 OMITTED
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	2N2060 2N2060A 2N2223 2N2223A	2N2480	2N2480A	Unit
Collector-Emitter Voltage	V_{CEO}	60	40	40	Vdc
Collector-Emitter Voltage	V_{CER}	80	-	-	Vdc
Collector-Base Voltage	V_{CB}	100	75	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0	5.0	5.0	Vdc
Collector Current	I_C	←500→			mAdc
Operating Junction Temperature	T_J	←200→			°C
Storage Temperature Range	T_{stg}	←-65 to +200→			°C
		One Side		Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 2.86		0.6 3.43	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.6 9.1		3.0 17.2	Watts mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 20 mAdc, I_B = 0)	2N2480, 2N2480A		40	-	
(I_C = 30 mAdc, I_B = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		60	-	
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, R_{BE} ≤ 10 ohms)	2N2060, 2N2060A, 2N2223, 2N2223A	BV_{CER}*	80	-	Vdc
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 100 μAdc, I_E = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		100	-	
	2N2480		75	-	
	2N2480A		80	-	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 100 μAdc, I_C = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		7.0	-	
	2N2480, 2N2480A		5.0	-	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N2480, 2N2480A		-	15	
(V_{CB} = 60 Vdc, I_E = 0)	2N2480		-	0.050	
	2N2480A		-	0.020	
(V_{CB} = 80 Vdc, I_E = 0)	2N2060, 2N2060A		-	0.002	
	2N2223, 2N2223A		-	0.010	
(V_{CB} = 80 Vdc, I_E = 0, T_A = 150°C)	2N2060, 2N2060A		-	10	
	2N2223, 2N2223A		-	15	
Emitter Cutoff Current		I_{EBO}			nAdc
(V_{BE} = 5.0 Vdc, I_C = 0)	2N2060, 2N2060A		-	2.0	
	2N2223, 2N2223A		-	10	
	2N2480		-	50	
	2N2480A		-	20	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A		25	75	
	2N2223, 2N2223A		15	-	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A		30	90	
	2N2223, 2N2223A		25	150	
	2N2480		20	-	
	2N2480A		35	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A		40	120	
	2N2480		30	350	
	2N2480A		50	200	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)*	2N2060, 2N2060A		50	150	
	2N2223, 2N2223A		50	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N2060A		-	0.6	
	2N2060, 2N2223, 2N2223A, 2N2480A		-	1.2	
	2N2480		-	1.3	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N2060, 2N2060A, 2N2223, 2N2223A, 2N2480A		-	0.9	
	2N2480		-	1.0	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N2223, 2N2223A, 2N2480, 2N2480A		50	-	
	2N2060, 2N2060A		60	-	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	2N2060, 2N2060A, 2N2223, 2N2223A		-	15	
	2N2480A		-	18	
	2N2480		-	20	
Input Capacitance		C_{ib}			pF
(V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	2N2060, 2N2060A, 2N2223, 2N2223A, 2N2480A		-	85	
Input Impedance		h_{ie}			ohms
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A		1000	4000	
	2N2480A		1000	5000	
Input Impedance		h_{ib}			ohms
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A, 2N2223, 2N2223A		20	30	
	2N2480A		20	35	
Voltage Feedback Ratio		h_{rb}			$X\ 10^{-4}$
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2223, 2N2223A		-	3.0	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A		50	150	
	2N2223, 2N2223A		40	120	
	2N2480A		50	300	
Output Admittance		h_{oe}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A, 2N2480A		4.0	16	
Output Admittance		h_{ob}			μmhos
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2223, 2N2223A		-	0.5	
Noise Figure		NF			dB
(I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, f = 1.0 kHz, BW = 1.0 Hz)	2N2480, 2N2480A		-	8.0	
(I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, f = 1.0 kHz, BW = 200 Hz)	2N2060, 2N2060A		-	8.0	
(I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz, BW = 15.7 kHz†)			-	8.0	

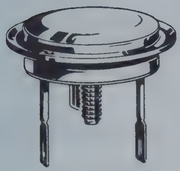
†Amplifier: 3.0 dB points at 25 Hz and 10 kHz with a roll-off of 6.0 dB per octave.

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
MATCHING CHARACTERISTICS				
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**			-
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A, 2N2223A		0.9	1.0	
2N2223, 2N2480, 2N2480A		0.8	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A		0.9	1.0	
2N2480, 2N2480A		0.8	1.0	
Base Voltage Differential	$\lvert V_{BE1}-V_{BE2}\rvert$			mVdc
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc) 2N2060A		-	3.0	
2N2060, 2N2223A, 2N2480A		-	5.0	
2N2480		-	10	
2N2223		-	15	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A, 2N2480A		-	5.0	
2N2480		-	10	
Base Voltage Differential Change	$\Delta(V_{BE1}-V_{BE2})$			mVdc
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C) 2N2060A		-	0.4	
2N2060		-	0.8	
2N2223, 2N2223A		-	2.0	
2N2480, 2N2480A		-	1.2	
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C) 2N2060		-	1.0	
2N2060A		-	0.5	
2N2223, 2N2223A		-	2.5	
2N2480, 2N2480A		-	1.5	

**The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2075 thru 2N2082 (GERMANIUM)
2N2075A thru 2N2082A



CASE 5
(TO-36)

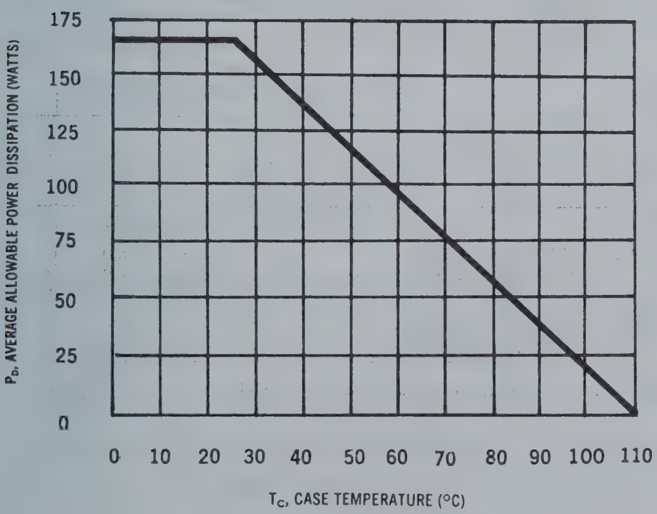
PNP germanium power transistors for high-power applications in high-reliability equipment.

MAXIMUM RATINGS

Rating	Symbol	2N2078 2N2082	2N2077 2N2081	2N2076 2N2080	2N2075 2N2079	Unit
Collector-Emitter Voltage	V_{CEO}	25	45	55	65	Vdc
Collector-Emitter Voltage	V_{CES}	40	50	70	80	Vdc
Collector-Base Voltage	V_{CB}	40	50	70	80	Vdc
Emitter-Base Voltage	V_{EB}	20	25	35	40	Vdc
Collector Current	I_C	15				Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	170				Watts
Operating Junction Temperature Range	T_J	-65 to +110				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W



POWER-TEMPERATURE DERATING CURVE

The maximum average power is related to maximum junction temperature by the thermal resistance factor.

This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

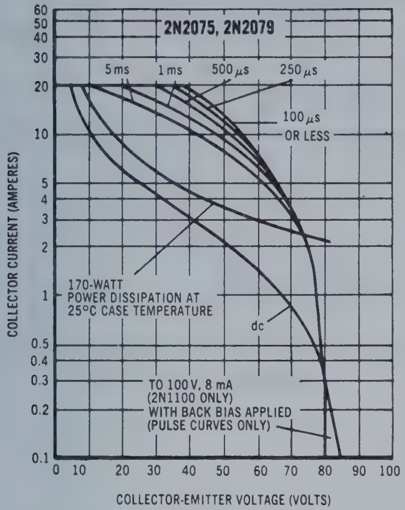
$$\text{allowable } P_D = \frac{110° - T_C}{0.5}$$

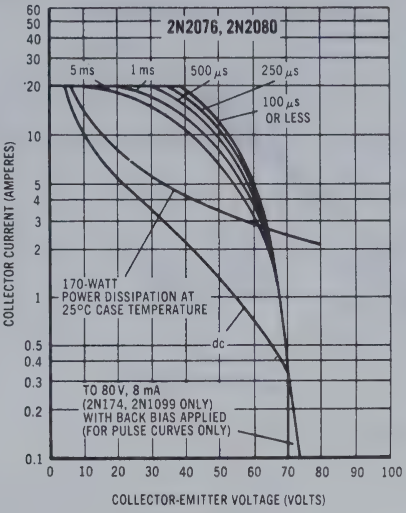
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

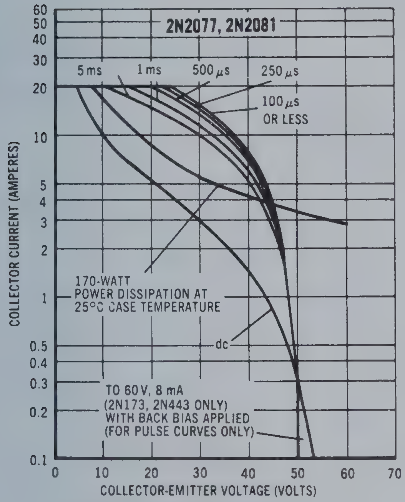
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1.0 Adc, I_B = 0)	2N2078, 2N2082	BV_{CEO}	25	-	Vdc
	2N2077, 2N2081		45	-	
	2N2076, 2N2080		55	-	
	2N2075, 2N2079		65	-	
Collector-Emitter Breakdown Voltage* (I_C = 300 mAdc, V_{BE} = 0)	2N2078, 2N2082	BV_{CES}	40	-	Vdc
	2N2077, 2N2081		50	-	
	2N2076, 2N2080		70	-	
	2N2075, 2N2079		80	-	
Floating Potential (V_{CB} = 40 Vdc, I_E = 0)	2N2078, 2N2082	V_{EBF}	-	1.0	Vdc
(V_{CB} = 50 Vdc, I_E = 0)	2N2077, 2N2081		-	1.0	
(V_{CB} = 70 Vdc, I_E = 0)	2N2076, 2N2080		-	1.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N2075, 2N2079		-	1.0	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	0.2	mAdc
(V_{CB} = $V_{CB(max)}$, V_{EB} = 1.5 Vdc)			-	4.0	
(V_{CB} = $V_{CB(max)}$, I_E = 0, T_C = +71°C)			-	15	
Emitter Cutoff Current (V_{BE} = $V_{BE(max)}$, I_C = 0)		I_{EBO}	-	4.0	mAdc
(V_{BE} = $V_{BE(max)}$, I_C = 0, T_C = +71°C)			-	15	
ON CHARACTERISTICS					
DC Current Gain (I_C = 1.2 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078	h_{FE}	25	100	-
	2N2079 thru 2N2082		40	160	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078		20	40	
	2N2079 thru 2N2082		35	70	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc, T_C = -55°C)	2N2075 thru 2N2078		15	-	
	2N2079 thru 2N2082		25	-	
(I_C = 12 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078		8	-	
	2N2079 thru 2N2082		12	-	
Collector-Emitter Saturation Voltage (I_C = 13 Adc, I_B = 2.0 Adc)	2N2075 & 76, 2N2079 & 80	$V_{CE(sat)}$	-	0.7	Vdc
	2N2077 & 78, 2N2081 & 82		-	0.9	
Base-Emitter On Voltage (I_C = 5.0 Adc, V_{CE} = 12 Vdc)		$V_{BE(on)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)		$f_{\alpha e}$	5.0	-	kHz
Rise Time		t_r	Typ		μs
(V_{CE} = 12 Vdc, $I_{C(on)}$ = 12 Adc, I_B = 2.0 Adc)	2N2075 thru 2N2078		9.0		
	2N2079 thru 2N2082		6.0		
Fall Time (V_{BE} = 6.0 Vdc, $I_{C(off)}$ = 0, R_{BE} = 10 ohms)	2N2075 thru 2N2078	t_f	12		μs
	2N2079 thru 2N2082		13		

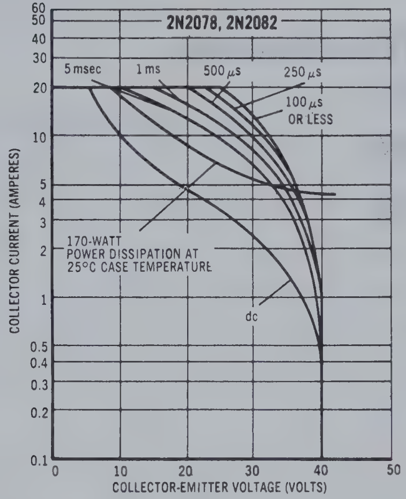
*To avoid excessive heating of collector junction, perform this test with a sweep method.

SAFE OPERATING AREAS





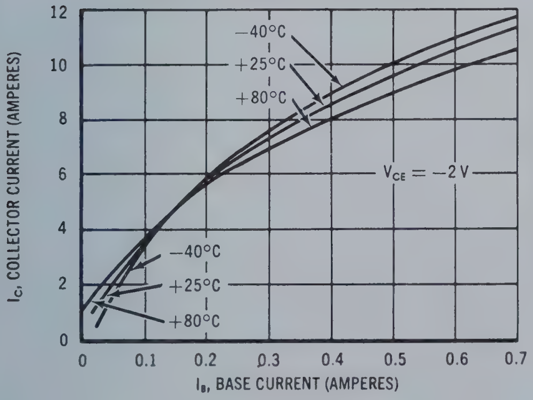




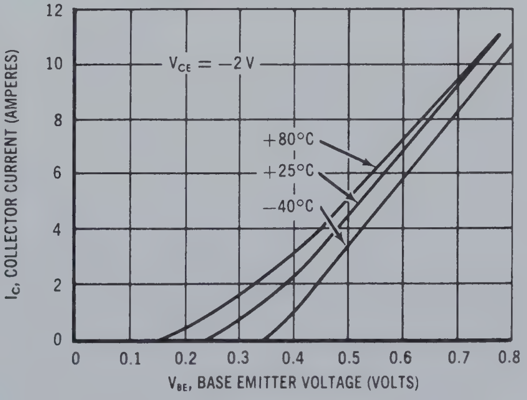
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N2075-2N2078

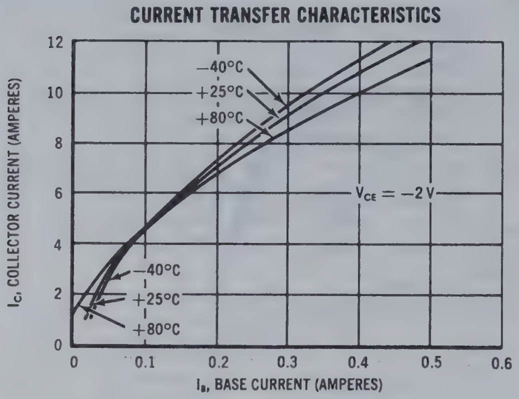
CURRENT TRANSFER CHARACTERISTICS

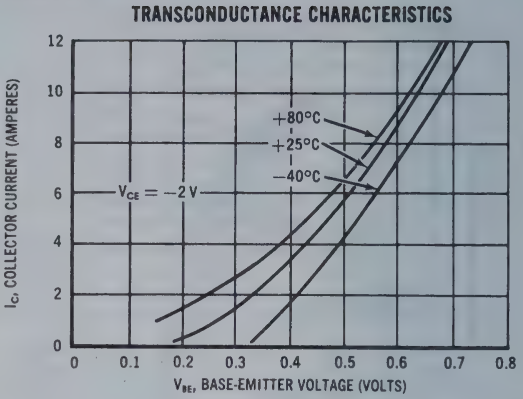


TRANSCONDUCTANCE CHARACTERISTICS



2N2079-2N2082



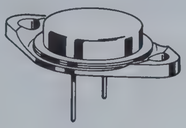


2N2096 (GERMANIUM)
2N2097
2N2099
2N2100

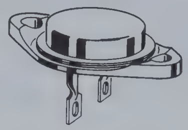
For Specifications, See 2N1204 Data.

2N2137 thru 2N2146 (GERMANIUM)
2N2137A thru 2N2146A

PNP germanium industrial power transistors for driver applications in high reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP2137,A etc. (TO-41 package)

MAXIMUM RATINGS

Apply also to standard, non-A series

Rating	Symbol	2N2137A 2N2142A	2N2138A 2N2143A	2N2139A 2N2144A	2N2140A 2N2145A	2N2141A 2N2146A	Unit
Collector-Base Voltage	V_{CB}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEO}	20	30	45	60	65	Vdc
Emitter-Base Voltage	V_{EB}	15	25	30	40	45	Vdc
Total Device Dissipation @ T_C = 25°C	P_D	70					Watts
Derate above 25°C		0.833					W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110					°C

ELECTRICAL CHARACTERISTICS

*Characteristics apply also to corresponding, non-A type numbers.

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage**		BV_{CEO}**				Vdc
(I_C = 500 mAdc, I_B = 0)	2N2137A, 2N2142A*		20	-	-	
	2N2138A, 2N2143A*		30	-	-	
	2N2139A, 2N2144A*		45	-	-	
	2N2140A, 2N2145A*		60	-	-	
	2N2141A, 2N2146A*		65			
Collector-Emitter Breakdown Voltage**		BV_{CES}**				Vdc
(I_C = 300 mAdc, V_{BE} = 0)	2N2137A, 2N2142A*		30	-	-	
	2N2138A, 2N2143A*		45	-	-	
	2N2139A, 2N2144A*		60	-	-	
	2N2140A, 2N2145A*		75	-	-	
	2N2141A, 2N2146A*		90	-	-	
Floating Potential		V_{EBF}				Vdc
(V_{CB} = 30 Vdc, I_E = 0)	2N2137A, 2N2142A*		-	-	1.0	
(V_{CB} = 45 Vdc, I_E = 0)	2N2138A, 2N2143A*		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N2139A, 2N2144A*		-	-	1.0	
(V_{CB} = 75 Vdc, I_E = 0)	2N2140A, 2N2145A*		-	-	1.0	
(V_{CB} = 90 Vdc, I_E = 0)	2N2141A, 2N2146A*		-	-	1.0	
Collector-Base Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.018	0.05	
($V_{CB} = V_{CB(max)}$, I_C = 0, T_C = +71° C)			-	0.75	5.0	
Collector-Base Cutoff Current†		I_{CBO1}				mAdc
($V_{CB} = V_{CB(max)}$, I_E = 0)			-	0.1	2.0	
Emitter-Base Cutoff Current		I_{EBO}				mAdc
($V_{BE} = V_{BE(max)}$, I_C = 0)			-	0.08	2.0	
($V_{BE} = V_{BE(max)}$, I_C = 0, T_C = +71° C)			-	0.5	5.0	
ON CHARACTERISTICS						
DC Current Gain						-
(I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)†	2N2137A-2N2141A*	h_{FE1}	30	45	60	
	2N2142A-2N2146A*		50	70	100	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N2137A-2N2141A*	h_{FE}	15	22	-	
	2N2142A-2N2146A*		25	33	-	
Collector-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 200 mAdc)		$V_{CE(sat)}$	-	0.12	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 200 mAdc)		$V_{BE(sat)}$	-	0.75	1.2	Vdc
DYNAMIC CHARACTERISTICS						
Common Emitter Cutoff Frequency (I_C = 2.0 Adc, V_{CE} = 6.0 Vdc)		$f_{\alpha e}$	12	20	-	kHz

**Sweep method: 1/2 cycle sine wave, 60 Hz .

FIGURE 1 — POWER TEMPERATURE DERATING CURVE

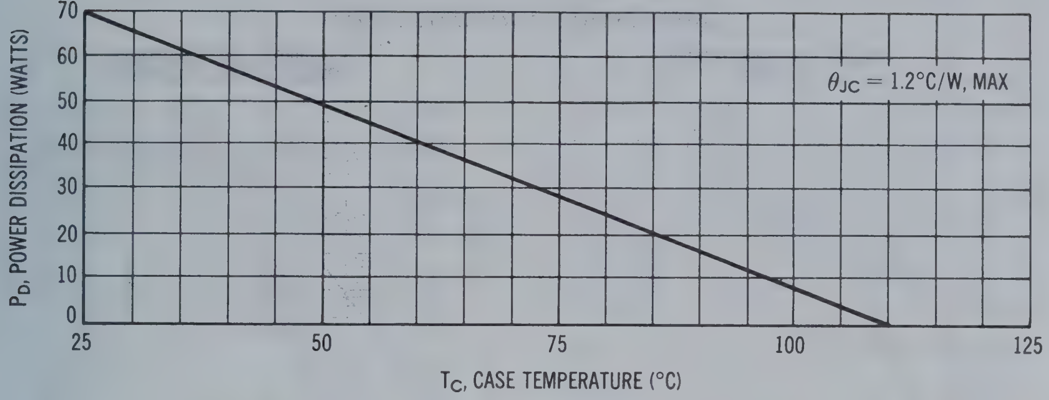
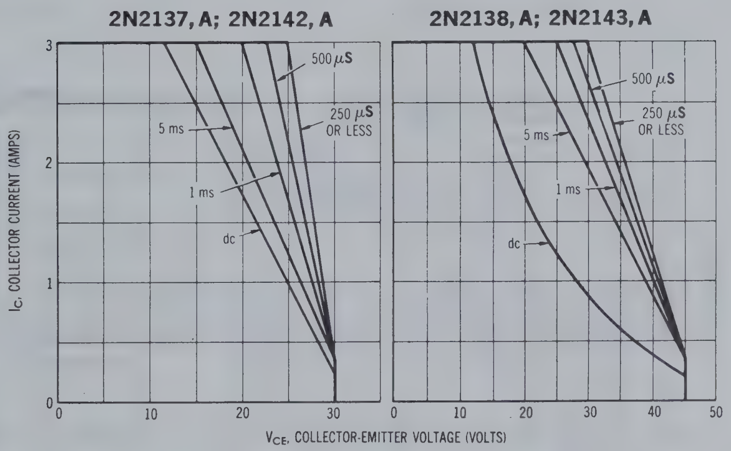
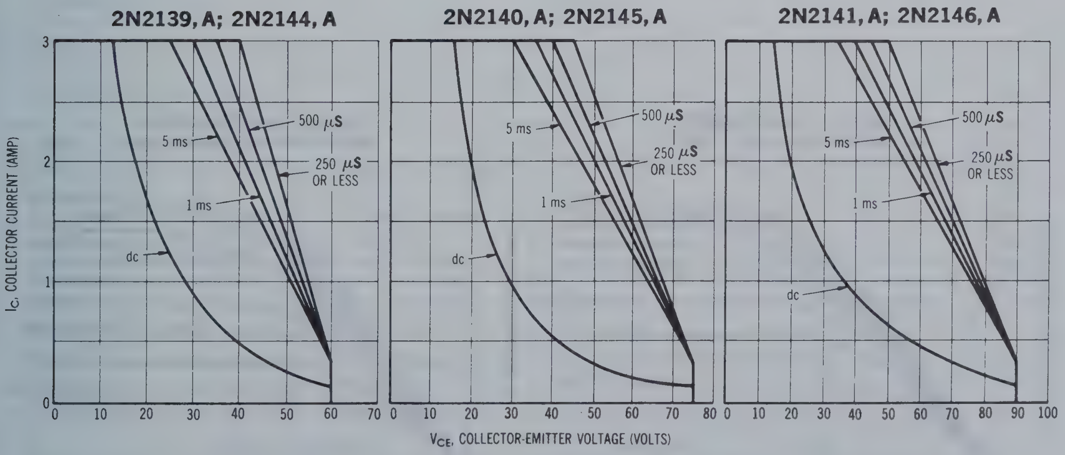


FIGURE 2 — ACTIVE REGION SAFE OPERATING AREAS

The active region safe operating area curves indicate I_C-V_{CE} limits to be observed in order to avoid secondary breakdown. (Secondary breakdown is independent of temperature and duty cycle.) These curves do not define operation in the avalanche region. To insure operation below the maximum junction temperature, power derating must be observed for both steady state and pulse conditions.





LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE
(ALL TYPES)

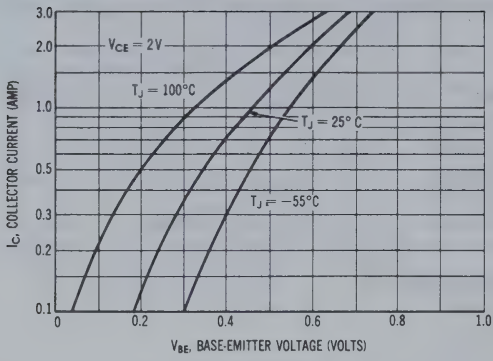


FIGURE 4 — INPUT ADMITTANCE
(2N2137A-2N2141A, 2N2137-2N2141)

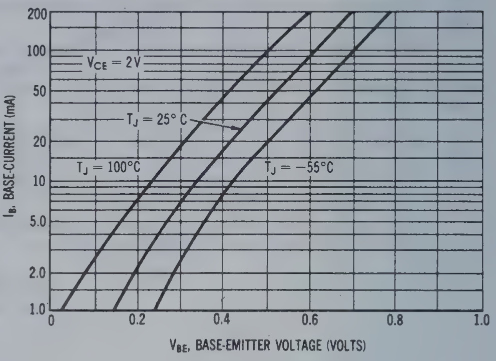


FIGURE 5 — INPUT ADMITTANCE
(2N2142A-2N2146A, 2N2142-2N2146)

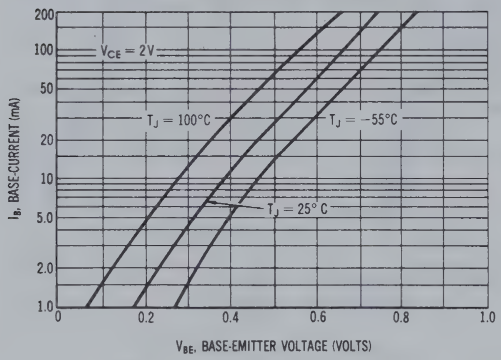


FIGURE 6 — NORMALIZED DC CURRENT GAIN
(ALL TYPES)

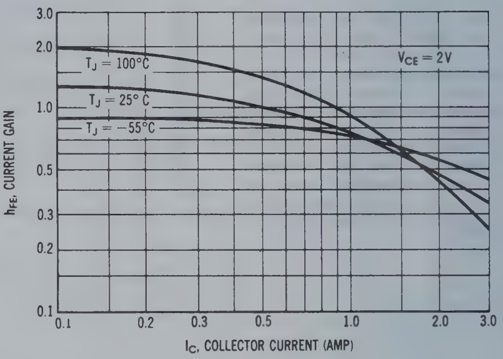


FIGURE 7 — SATURATION REGION
(2N2137A-2N2141A, 2N2137-2N2141)

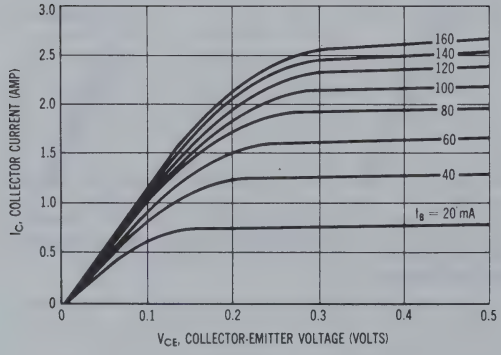
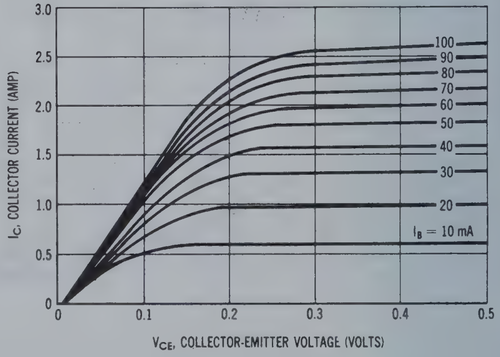
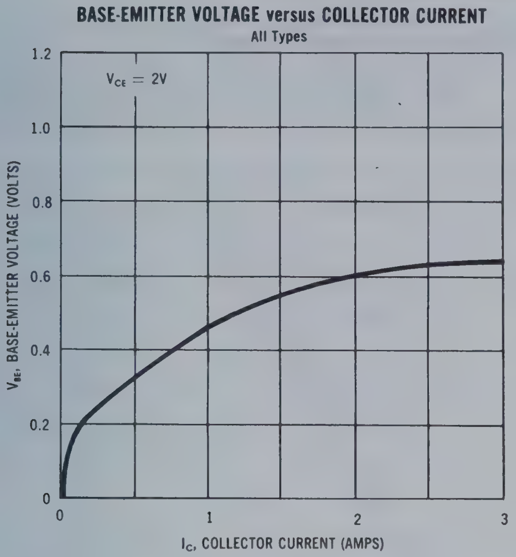
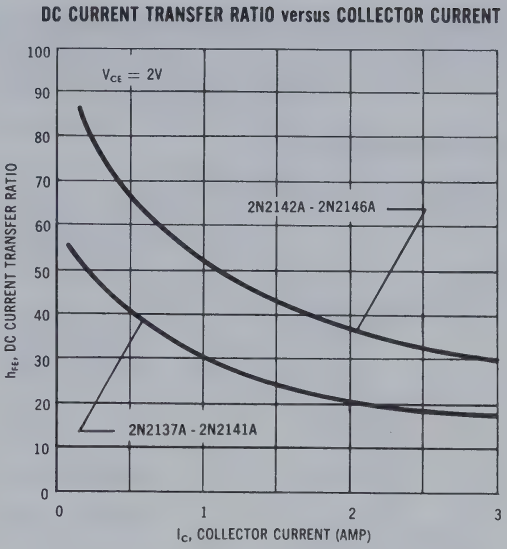


FIGURE 8 — SATURATION REGION
(2N2142A-2N2146A, 2N2142-2N2146)



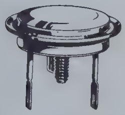
INPUT & TRANSFER CHARACTERISTICS





2N2152 thru 2N2154 (GERMANIUM)
2N2156 thru 2N2158

CASE 5
(TO-36)



PNP germanium power transistors for high-power, high-gain applications in high-reliability industrial equipment.

MAXIMUM RATINGS

Rating	Symbol	2N2152 2N2156	2N2153 2N2157	2N2154 2N2158	Unit
Collector-Emitter Voltage	V_{CEO}	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	30	40	Vdc
Collector Current	I_C		30		Adc
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D		170 0.5		Watts W/°C
Operating Junction Temperature Range	T_J		-65 to +110		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

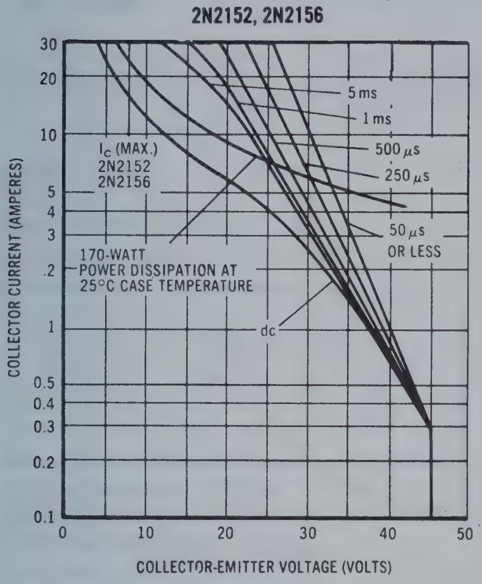
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

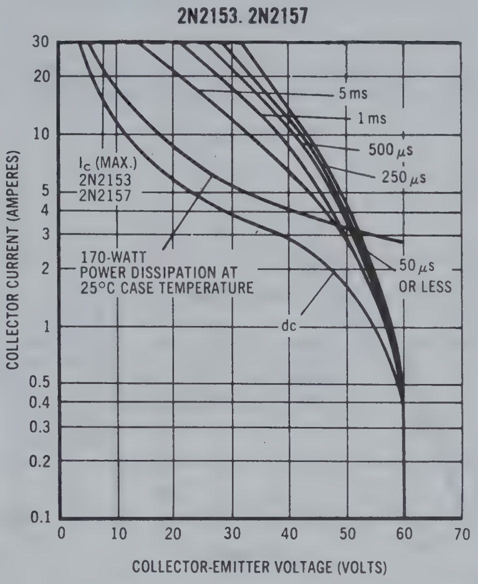
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 1.0 Adc, I_B = 0) 2N2152, 2N2156	BV_{CEO}*	30	-	-	Vdc
2N2153, 2N2157		45	-	-	
2N2154, 2N2158		60	-	-	
Collector-Emitter Breakdown Voltage* (I_C = 300 mAdc, V_{BE} = 0) 2N2152, 2N2156	BV_{CES}*	45	-	-	Vdc
2N2153, 2N2157		60	-	-	
2N2154, 2N2158		75	-	-	
Floating Potential (V_{CB} = 45 Vdc, I_E = 0) 2N2152, 2N2156	V_{EBF}	-	-	1.0	Vdc
(V_{CB} = 60 Vdc, I_E = 0) 2N2153, 2N2157		-	-	1.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N2154, 2N2158		-	-	1.0	
Collector Cutoff Current (V_{CB} = 2V, I_E = 0)	I_{CBO}	-	0.08	0.2	mAdc
(V_{CB} = 45 Vdc, I_E = 0) 2N2152, 2N2156		-	0.9	4.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N2153, 2N2157		-	0.9	4.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N2154, 2N2158		-	0.9	4.0	
(V_{CB} = $V_{CB(max)}$, I_E = 0, T_C = 71°C)		-	4.0	15	
Emitter Cutoff Current (V_{BE} = 25 Vdc, I_C = 0)	I_{EBO}	-	0.2	4.0	mAdc
(V_{BE} = 30 Vdc, I_C = 0)		-	0.2	4.0	
(V_{BE} = 40 Vdc, I_C = 0)		-	0.2	4.0	
(V_{BE} = $V_{EB(max)}$, I_C = 0, T_C = 71°C)		-	2.7	15	
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 Adc, V_{CB} = 2 Vdc) 2N2152, 2N2153, 2N2154	h_{FE}	50	75	100	-
2N2156, 2N2157, 2N2158		80	105	160	
(I_C = 15 Adc, V_{CB} = 2 Vdc) 2N2152, 2N2153, 2N2154		25	47	-	
2N2156, 2N2157, 2N2158		40	63	-	
(I_C = 25 Adc, V_{CB} = 2 Vdc)		15	38	-	
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 500 mAdc)	$V_{CE(sat)}$	-	0.06	0.1	Vdc
(I_C = 25 Adc, I_B = 2 Adc)		-	0.2	0.3	
Base-Emitter On Voltage (I_C = 5.0 Adc, I_B = 500 mAdc)	$V_{BE(on)}$	-	0.65	1.0	Vdc
(I_C = 25 Adc, I_B = 2 Adc)		-	1.0	2.0	
SMALL SIGNAL CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)	$f_{\alpha e}$	2.0	2.7	-	kHz

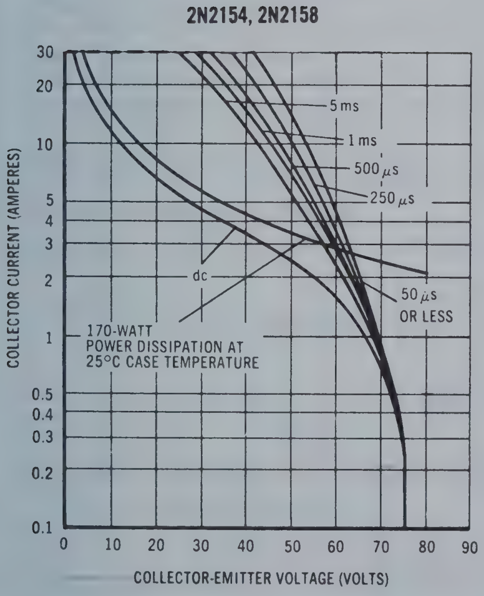
*To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.

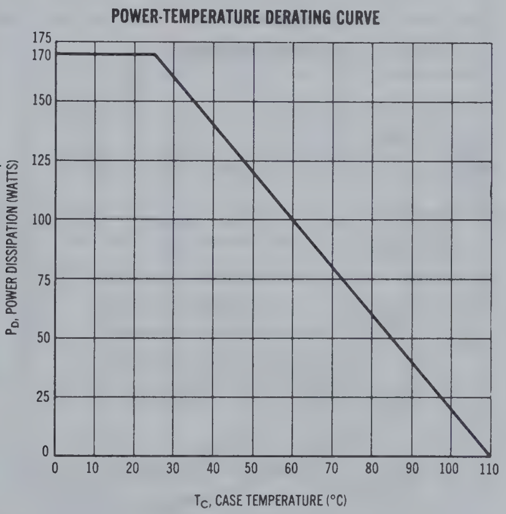
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.









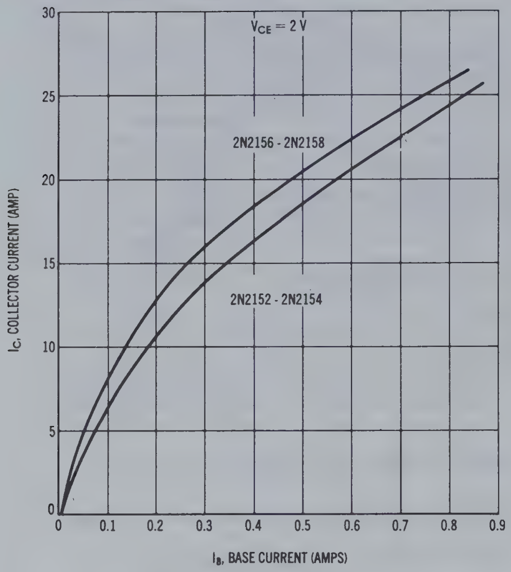
The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110^{\circ} - T_C}{0.5}$$

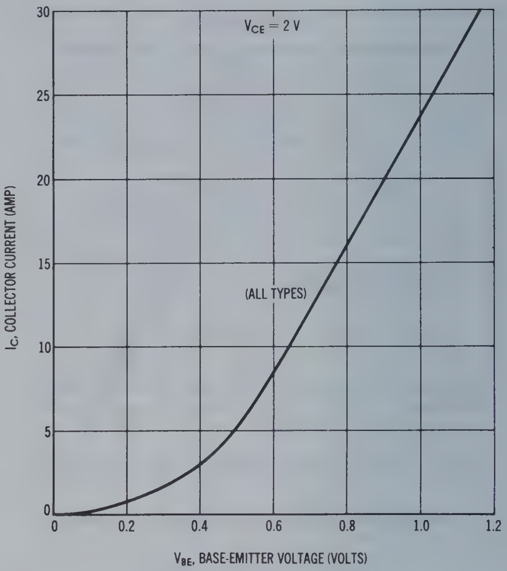
2N2152 thru 2N2154 , 2N2156 thru 2N2158 (continued)

TYPICAL INPUT AND TRANSFER CHARACTERISTICS

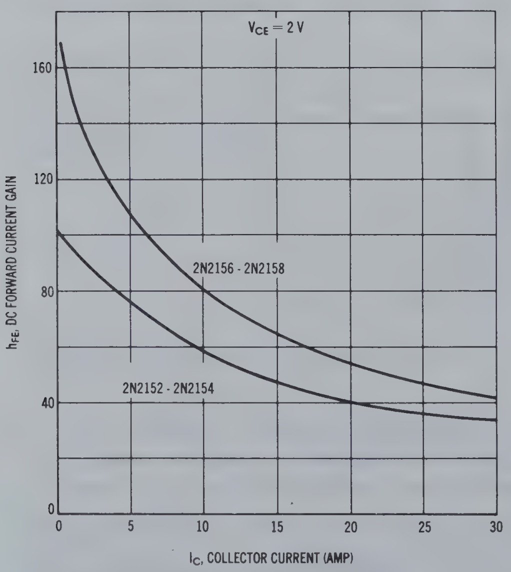
COLLECTOR CURRENT
versus BASE CURRENT



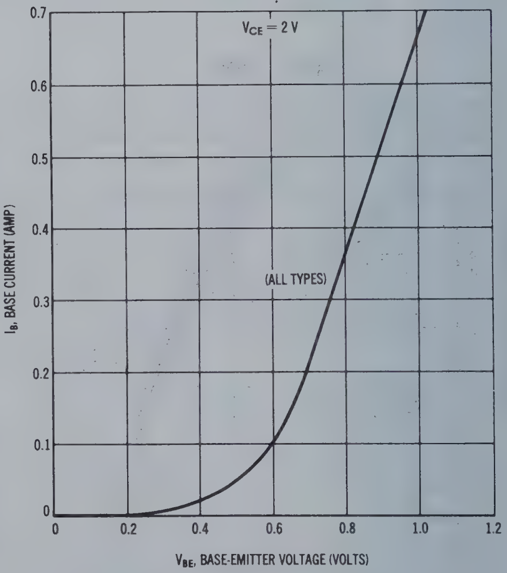
COLLECTOR CURRENT
versus BASE-EMITTER VOLTAGE



DC CURRENT GAIN
versus COLLECTOR CURRENT



BASE CURRENT versus
BASE-EMITTER VOLTAGE



2N2171 FOR SPECIFICATIONS, SEE 2N381 DATA.

2N2192, A, B thru 2N2195, A, B
(SILICON)

CASE 31
(TO-5)
Collector connected to case

NPN silicon annular transistors for high-current switching and amplifier applications.

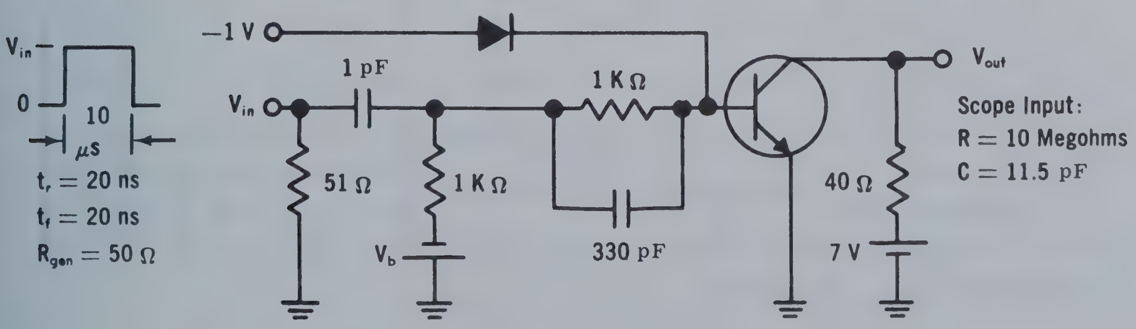
MAXIMUM RATINGS

Rating	Symbol	2N2192 2N2192A 2N2192B 2N2194 2N2194A 2N2194B	2N2193 2N2193A 2N2193B	2N2195 2N2195A 2N2195B	Unit
Collector-Base Voltage	V_{CB}	60	80	45	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	8.0	5.0	Vdc
Collector Current	I_C	1.0	1.0	1.0	Adc
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.8 4.56	0.8 4.56	0.6 3.43	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	← 2.8 → ← 16 →			Watts mW/°C
Junction Temperature, Operating	T_J	-65 to +200			°C
Storage Temperature Range	T_{stg}	-65 to +200			°C

FIGURE 1

2N2193, A, B
2N2194, A, B } $V_{in} = 15$ V, $V_b = 15$ V

2N2192, A, B — $V_{in} = 7.5$ V, $V_b = 7.5$ V


V_{in}
0
10 µs
$t_r = 20$ ns
$t_f = 20$ ns
$R_{gen} = 50\ \Omega$
−1 V
V_{in}
1 pF
51 Ω
1 KΩ
V_b
1 KΩ
330 pF
40 Ω
7 V
V_{out}
Scope Input:
R = 10 Megohms
C = 11.5 pF

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N2192, A, B, 2N2194, A, B	BV_{CBO}	60	-	Vdc
	2N2193, A, B		80	-	
	2N2195, A, B		45		
Collector Emitter-Open Base Sustain Voltage [1] (I_C = 25 mA pulsed, I_B = 0)	2N2192, A, B, 2N2194, A, B	$V_{CEO(sus)}$	40	-	Vdc
	2N2193, A, B		50	-	
	2N2195, A, B		25	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N2192, A, B, 2N2194, A, B,	BV_{EBO}	5.0	-	Vdc
	2N2195, A, B		5.0	-	
	2N2193, A, B		8.0	-	
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	2N2192, A, B, 2N2194, A B	I_{CBO}	-	0.010	μAdc
	2N2195, A, B			0.100	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N2192, A, B		-	15	
	2N2194, A, B		-	25	
	2N2195, A, B		-	50	
(V_{CB} = 60 Vdc, I_E = 0)	2N2193, A, B		-	0.010	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	2N2193, A, B		-	25	
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	2N2192, A, B, 2N2194, A, B	I_{EBO}	-	0.050	μAdc
	2N2195, A, B		-	0.100	
(V_{EB} = 5 Vdc, I_C = 0)	2N2193, A, B		-	0.050	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	2N2192 thru 2N2195	$V_{CE(sat)}$	-	0.35	Vdc
	2N2192A thru 2N2195A		-	0.25	
	2N2192B thru 2N2195B		-	0.18	
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$	- -	1.3	Vdc
DC Current Gain [1] (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B, 2N2193, A, B	h_{FE}	15	-	-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		75	-	
	2N2193, A, B		30	-	
	2N2194, A, B		15	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2192, A, B		35	-	
	2N2193, A, B		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		100	300	
	2N2193, A, B		40	120	
	2N2194, A, B		20	60	
	2N2195, A, B		20	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N2192, A, B		70	-	
	2N2193, A, B		30	-	
	2N2194, A, B		15	-	
	2N2195, A, B		10	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		35	-	
	2N2193, A, B		20	-	
	2N2194, A, B		12	-	
(I_C = 1.0 Adc, V_{CE} = 10 Vdc)	2N2192, A, B, 2N2193, A, B		15	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	-	20	pF
Small Signal Current Gain (I_C = 50 mA, V_{CE} = 10 V, f = 20 MHz)		h_{fe}	2.5	-	-
Rise Time	2N2192-94, 2N2192A-94A, 2N2192B-94B	t_r	-	70	ns
Storage Time		t_s	-	150	ns
Fall Time		t_f	-	50	ns

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[1] Pulse Test: PW ≤ 300 μs Duty Cycle ≤ 2%

2N2212 (GERMANIUM)

PNP GERMANIUM POWER TRANSISTORS

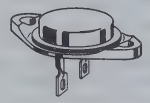
. . . designed for high-current switching applications requiring low saturation voltages, short switching times and good collector-emitter sustaining capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltage —
  $V_{CE(SAT)} = 0.5$ Vdc (Max) @$I_C = 5.0$ Adc

10 AMPERE

PNP ADE GERMANIUM POWER TRANSISTORS

120 VOLTS
102 WATTS



MAXIMUM RATINGS

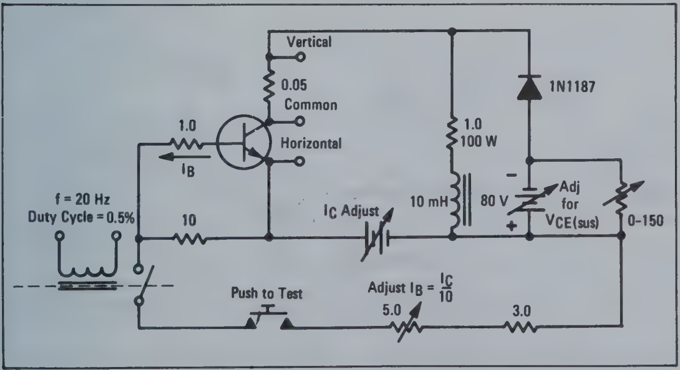
Rating	Symbol	Value	Unit
*Collector-Emitter Voltage	V_{CER}	120	Vdc
*Collector-Base Voltage	V_{CB}	120	Vdc
*Emitter-Base Voltage	V_{EB}	1.5	Vdc
*Collector Current - Continuous	I_C	10	Adc
*Base Current - Continuous	I_B	3.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	102 1.2	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

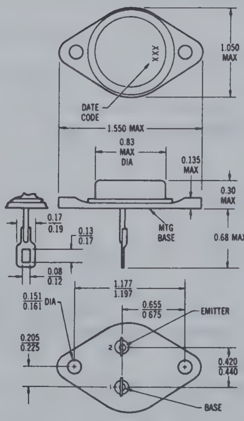
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
*Thermal Resistance, Junction to Case	θ_{JC}	0.83	°C/W

*Indicates JEDEC Registered Data.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
0.05
Common
Horizontal
1.0
I_B
1N1187
1.0
100 W
10 mH
80 V
Adj
for
$V_{CE(sus)}$
0-150
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0
-
+


XXX
DATE CODE
1.050 MAX
1.550 MAX
0.83 MAX DIA
0.135 MAX
0.30 MAX
0.68 MAX
MTG BASE
0.17 / 0.19
0.13 / 0.17
0.08 / 0.12
1.177 / 1.197
0.151 / 0.161 DIA
0.655 / 0.675
EMITTER
0.205 / 0.225
0.420 / 0.440
BASE
1
2

Collector Connected to Case

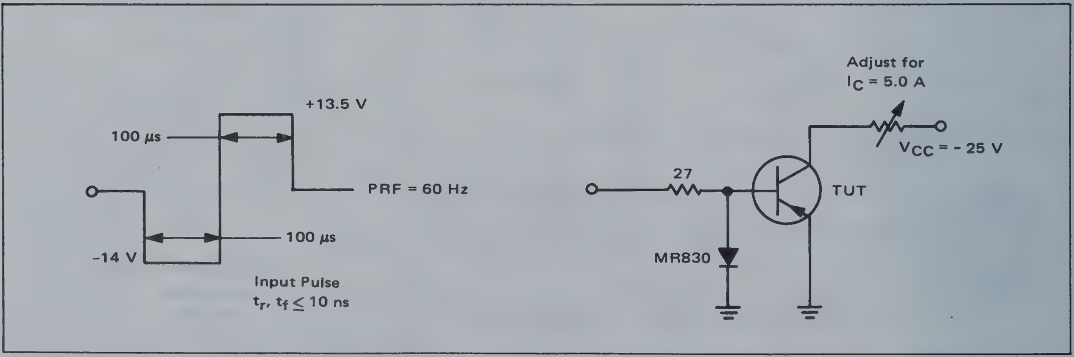
CASE 4–04
(TO-41)

ELECTRICAL CHARACTERISTICS (T$_C$ = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	60	-	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 5.0 Adc, I_B = 0)	$V_{CE(sus)}$	60	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 120 Vdc, R_{BE} = 100 Ohms)	I_{CER}	-	50	mAdc
*Collector Cutoff Current (V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	I_{CEX}	-	20	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0) *(V_{CB} = 100 Vdc, I_E = 0)	I_{CBO}	- -	200 2.0	µAdc mAdc
Emitter Cutoff Current (V_{EB} = 0.75 Vdc, I_C = 0)	I_{EBO}	-	25	mAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 0.6 Adc, V_{CE} = 1.0 Vdc) (I_C = 1.2 Adc, V_{CE} = 1.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	50 60 50	200 200 120	-
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter On Voltage (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)	h_{fe}	15	-	-
SWITCHING CHARACTERISTICS				
Rise Time (I_C = 5.0 Adc, I_{B1} = 0.5 Adc, I_{B2} = 0.5 Adc) (See Figure 2)	t_r	-	7.0	µs
Storage Time	t_s	-	10	µs
Fall Time	t_f	-	8.0	µs

*Indicates JEDEC Registered Data.

FIGURE 2 — SWITCHING TIME TEST CIRCUIT



2N2218,A, 2N2219,A 2N2221,A(SILICON) 2N2222,A, 2N5581, 2N5582

NPN SILICON ANNULAR HERMETIC TRANSISTORS

. . . widely used "Industry Standard" transistors for applications as medium-speed switches and as amplifiers from audio to VHF frequencies.

- DC Current Gain Specified – 1.0 to 500 mAdc
- Low Collector-Emitter Saturation Voltage –
  $V_{CE(sat)}$ @ I_C = 500 mAdc
  = 1.6 Vdc (Max) – Non-A Suffix
  = 1.0 Vdc (Max) – A-Suffix
- High Current-Gain–Bandwidth Product –
  f_T = 250 MHz (Min) @ I_C = 20 mAdc – All Types Except
  = 300 MHz (Min) @ I_C = 20 mAdc – 2N2219A, 2N2222A, 2N5582
- Complements to PNP 2N2904,A thru 2N2907,A
- JAN/JANTX Available for all devices

NPN SILICON SWITCHING AND AMPLIFIER TRANSISTORS

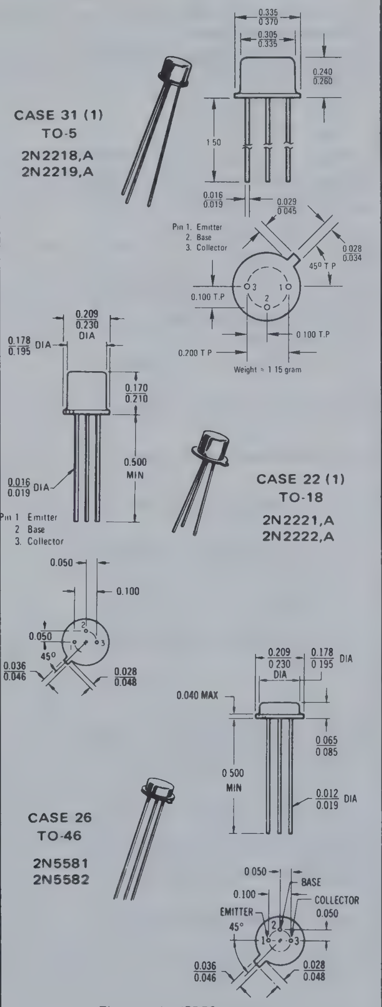
SELECTION GUIDE

Device Type	Characteristic BV_{CEO} I_C = 10 mAdc Volts	h_{FE} I_C = 150 mAdc Min/Max	 I_C = 500 mAdc Min	Package
2N2218 2N2219	30	40/120 100/300	20 30	TO-5
2N2221 2N2222	30	40/120 100/300	20 30	TO-18
2N5581 2N5582	40	40/120 100/300	25 40	TO-46
2N2218A 2N2219A	40	40/120 100/300	25 40	TO-5
2N2221A 2N2222A	40	40/120 100/300	25 40	TO-18

*MAXIMUM RATINGS

Rating	Symbol	2N2218 2N2219 2N2221 2N2222	2N2218A 2N2219A 2N2221A 2N2222A	2N5581 2N5582	Unit
Collector-Emitter Voltage	V_{CEO}	30	40	40	Vdc
Collector-Base Voltage	V_{CB}	60	75	75	Vdc
Emitter-Base Voltage	V_{EB}	5.0	6.0	6.0	Vdc
Collector Current – Continuous	I_C	800	800	800**	mAdc
		2N2218,A 2N2219,A	2N2221,A 2N2222,A	2N5581 2N5582	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 5.33	0.5 3.33	0.5 3.33	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.0 20	1.8 12	2.0 11.43	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +200	→	°C

*Indicates JEDEC Registered Data.
**Motorola Guarantees this Data in Addition to JEDEC Registered Data.


0.335
0.370
0.305
0.335
0.240
0.260
1 50
0.016
0.019
0.029
0.045
Pin 1. Emitter
2. Base
3. Collector
0.028
0.034
45° T P
0.100 T.P
0 100 T.P
0.200 T P
Weight ≈ 1 15 gram
0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
Pin 1 Emitter
2 Base
3. Collector
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
0.209
0 230
DIA
0.178
0 195
DIA
0.040 MAX
0 065
0 085
0 500
MIN
0.012
0.019
DIA
0 050
BASE
0.100
COLLECTOR
EMITTER
0.050
45°
0.036
0.046
0.028
0.048

CASE 31 (1)
TO-5
2N2218,A
2N2219,A

CASE 22 (1)
TO-18
2N2221,A
2N2222,A

CASE 26
TO-46
2N5581
2N5582

The respective JEDEC registered dimensions and notes apply

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 10 mAdc, I_B = 0)	Non-A Suffix		30	–	
	A-Suffix, 2N5581,2N5582		40	–	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	Non-A Suffix		60	–	
	A-Suffix, 2N5581,2N5582		75	–	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)	Non-A Suffix		5.0	–	
	A-Suffix, 2N5581,2N5582		6.0	–	
Collector Cutoff Current		I_{CEX}			nAdc
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	A-Suffix, 2N5581,2N5582		–	10	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0)	Non-A Suffix		–	0.01	
(V_{CB} = 60 Vdc, I_E = 0)	A-Suffix, 2N5581,2N5582		–	0.01	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	Non-A Suffix		–	10	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	A-Suffix, 2N5581,2N5582		–	10	
Emitter Cutoff Current		I_{EBO}			nAdc
(V_{EB} = 3.0 Vdc, I_C = 0)	A-Suffix, 2N5581,2N5582		–	10	
Base Cutoff Current		I_{BL}			nAdc
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	A-Suffix		–	20	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2218,A,2N2221,A,2N5581(1)		20	–	
	2N2219,A,2N2222,A,2N5582(1)		35	–	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2218,A,2N2221,A,2N5581		25	–	
	2N2219,A,2N2222,A,2N5582		50	–	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2218,A,2N2221,A,2N5581(1)		35	–	
	2N2219,A,2N2222,A,2N5582(1)		75	–	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2218A,2N2221A,2N5581		15	–	
	2N2219A,2N2222A,2N5582		35	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)(1)	2N2218,A,2N2221,A,2N5581		40	120	
	2N2219,A,2N2222,A,2N5582		100	300	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)(1)	2N2218A,2N2221A,2N5581		20	–	
	2N2219A,2N2222A,2N5582		50	–	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)(1)	2N2218,2N2221		20	–	
	2N2219,2N2222		30	–	
	2N2218A,2N2221A,2N5581		25	–	
	2N2219A,2N2222A,2N5582		40	–	
Collector-Emitter Saturation Voltage(1)		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	Non-A Suffix		–	0.4	
	A-Suffix, 2N5581,2N5582		–	0.3	
(I_C = 500 mAdc, I_B = 50 mAdc)	Non-A Suffix		–	1.6	
	A-Suffix, 2N5581,2N5582		–	1.0	
Base-Emitter Saturation Voltage(1)		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	Non-A Suffix		0.6	2.0	
	A-Suffix, 2N5581,2N5582		0.6	1.2	
(I_C = 500 mAdc, I_B = 50 mAdc)	Non-A Suffix		–	2.6	
	A-Suffix, 2N5581,2N5582		–	2.0	

*ELECTRICAL CHARACTERISTICS (Continued)

Characteristic		Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product(2)		f_T			MHz
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	All Types, Except		250	–	
	2N2219A,2N2222A,2N5582		300	–	
Output Capacitance(3) (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	–	8.0	pF
Input Capacitance(3)		C_{ib}			pF
(V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	Non-A Suffix		–	30	
	A-Suffix, 2N5581,2N5582		–	25	
Input Impedance		h_{ie}			k ohms
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		1.0	3.5	
	2N2219A,2N2222A,2N5582		2.0	8.0	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		0.2	1.0	
	2N2219A,2N2222A,2N5582		0.25	1.25	
Voltage Feedback Ratio		h_{re}			$\times 10^{-4}$
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		–	5.0	
	2N2219A,2N2222A,2N5582		–	8.0	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		–	2.5	
	2N2219A,2N2222A,2N5582		–	4.0	
Small-Signal Current Gain		h_{fe}			–
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		30	150	
	2N2219A,2N2222A,2N5582		50	300	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		50	300	
	2N2219A,2N2222A,2N5582		75	375	
Output Admittance		h_{oe}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		3.0	15	
	2N2219A,2N2222A,2N5582		5.0	35	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N2218A,2N2221A,2N5581		10	100	
	2N2219A,2N2222A,2N5582		25	200	
Collector-Base Time Constant (I_E = 20 mAdc, V_{CB} = 20 Vdc, f = 31.8 MHz)	A-Suffix, 2N5581,2N5582	$r_b'C_c$	–	150	ps
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz)	2N2219A,2N2222A	NF	–	4.0	dB

SWITCHING CHARACTERISTICS (A-Suffix, 2N5581 and 2N5582)

Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 14)	t_d	–	10	ns
Rise Time		t_r	–	25	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc) (Figure 15)	t_s	–	225	ns
Fall Time		t_f	–	60	ns
Active Region Time Constant** (I_C = 150 mAdc, V_{CE} = 30 Vdc)		T_A	–	2.5	ns

*Indicates JEDEC Registered Data.

**Motorola Guarantees this Data in Addition to JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

(3)2N5581 and 2N5582 are Listed C_{cb} and C_{eb} for these conditions and values.

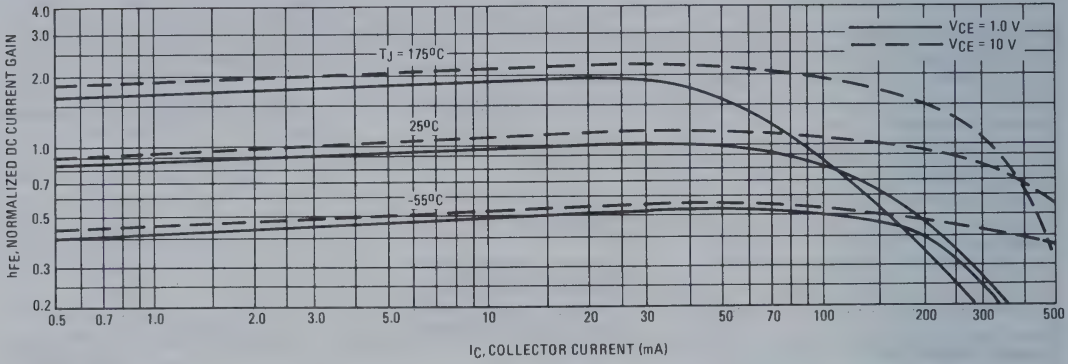


FIGURE 1 – NORMALIZED DC CURRENT GAIN

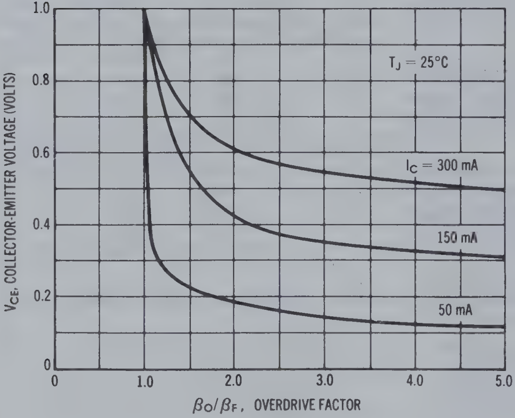


FIGURE 2 – COLLECTOR CHARACTERISTICS IN SATURATION REGION

This graph shows the effect of base current on collector current. β_o (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_c/I_{BF} in a circuit.

EXAMPLE: For type 2N2219, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at $I_c = 150$ mA an overdrive factor of at least 2.5 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is approximately 0.62 of h_{FE} @ 10 volts. Using the guaranteed minimum gain of 100 @ 150 mA and 10 V, $\beta_o = 62$ and substituting values in the overdrive equation, we find:

$$\frac{\beta_o}{\beta_F} = \frac{h_{FE} \text{ @ } 1.0\,\text{V}}{I_c/I_{BF}} \qquad 2.5 = \frac{62}{150/I_{BF}} \qquad I_{BF} \approx 6.0 \text{ mA}$$

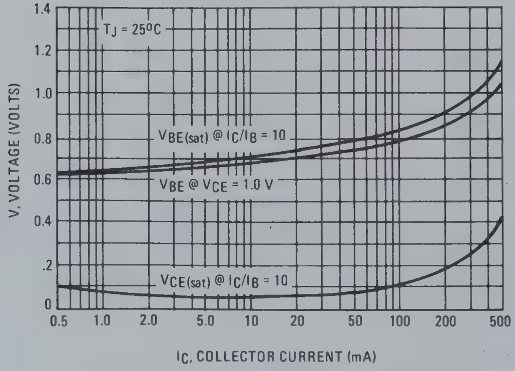


FIGURE 3 – "ON" VOLTAGES

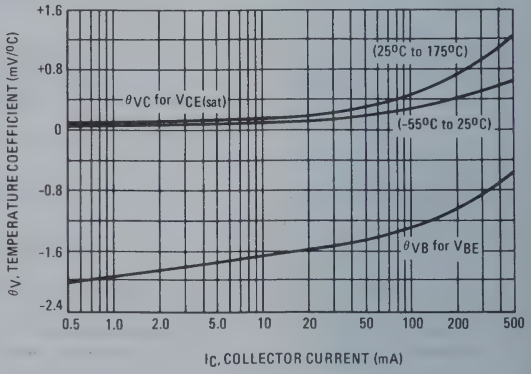


FIGURE 4 – TEMPERATURE COEFFICIENTS

NOISE FIGURE

V_{CE} = 10 V, T_A = 25°C

FIGURE 5 – FREQUENCY EFFECTS

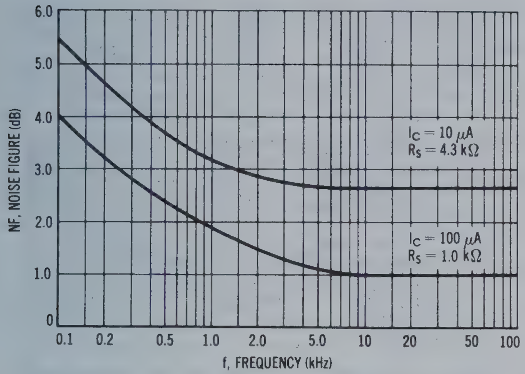
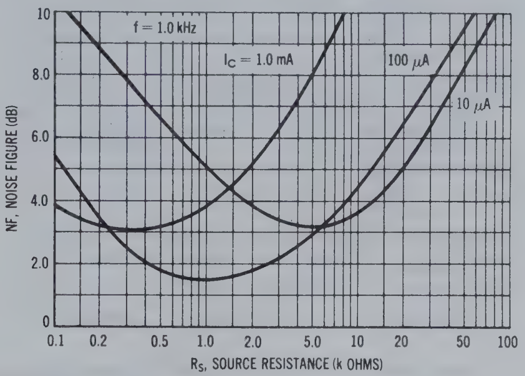


FIGURE 6 – SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 7 – INPUT IMPEDANCE

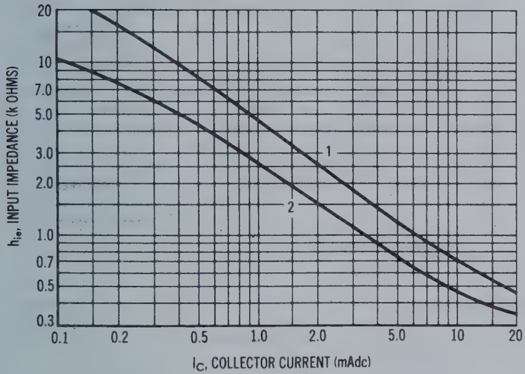


FIGURE 8 – VOLTAGE FEEDBACK RATIO

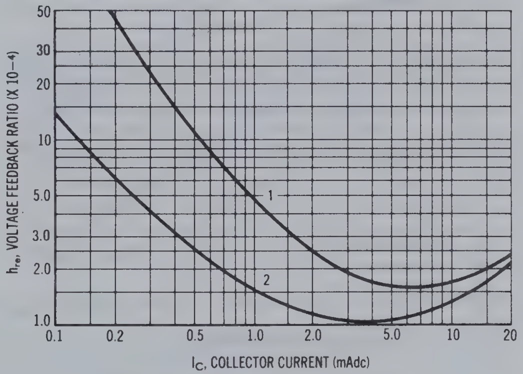


FIGURE 9 – CURRENT GAIN

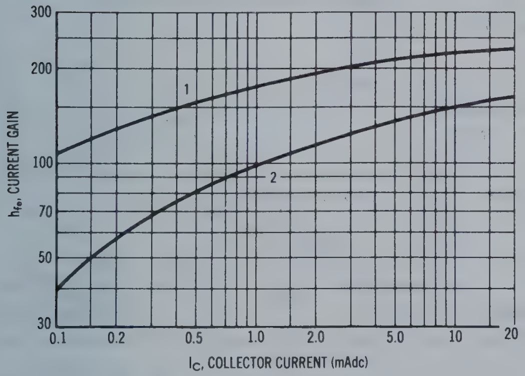
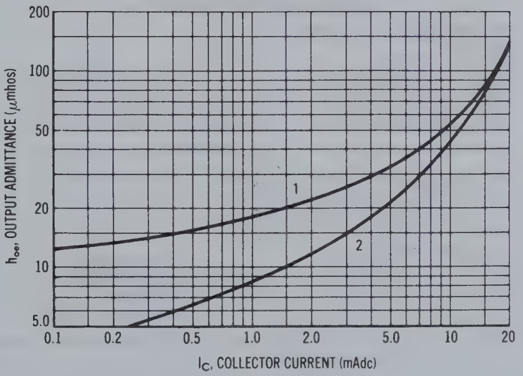


FIGURE 10 – OUTPUT ADMITTANCE



SWITCHING TIME CHARACTERISTICS

FIGURE 11 – TURN-ON TIME

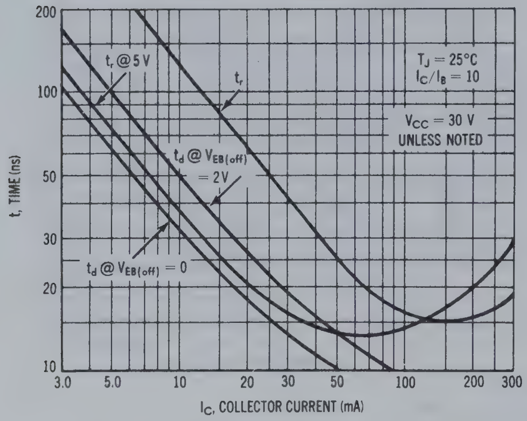


FIGURE 12 – CHARGE DATA

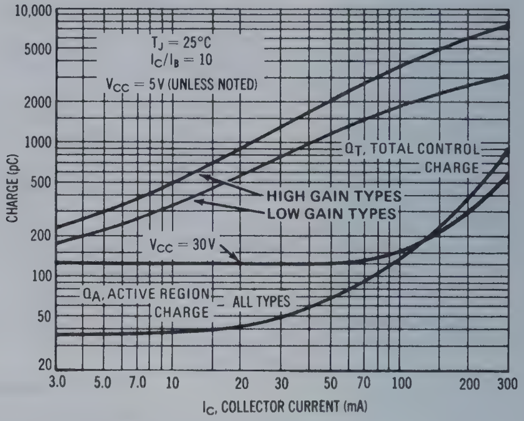


FIGURE 13 – TURN OFF BEHAVIOR

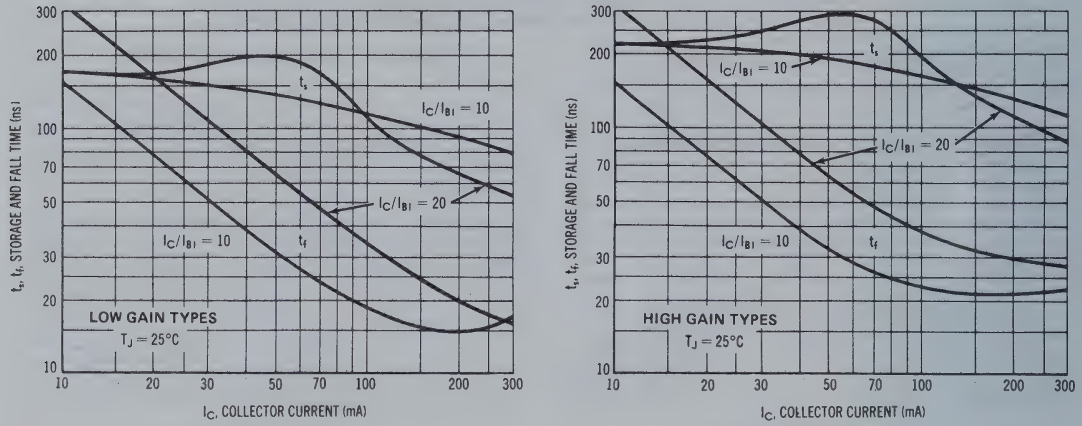


FIGURE 14 – DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

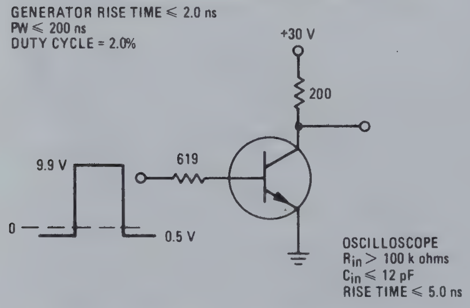

GENERATOR RISE TIME ≤ 2.0 ns
PW ≤ 200 ns
DUTY CYCLE = 2.0%
+30 V
200
9.9 V
619
0
0.5 V
OSCILLOSCOPE
R_{in} > 100 k ohms
C_{in} ≤ 12 pF
RISE TIME ≤ 5.0 ns

FIGURE 15 – STORAGE TIME AND FALL TIME EQUIVALENT TEST CIRCUIT

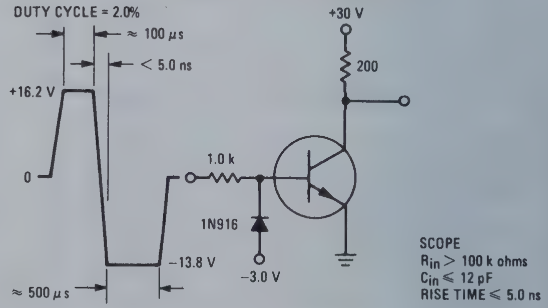

DUTY CYCLE = 2.0%
≈ 100 μs
< 5.0 ns
+16.2 V
0
−13.8 V
≈ 500 μs
1.0 k
1N916
−3.0 V
+30 V
200
SCOPE
R_{in} > 100 k ohms
C_{in} ≤ 12 pF
RISE TIME ≤ 5.0 ns

FIGURE 16 – CURRENT-GAIN–BANDWIDTH PRODUCT AND COLLECTOR-BASE TIME CONSTANT DATA

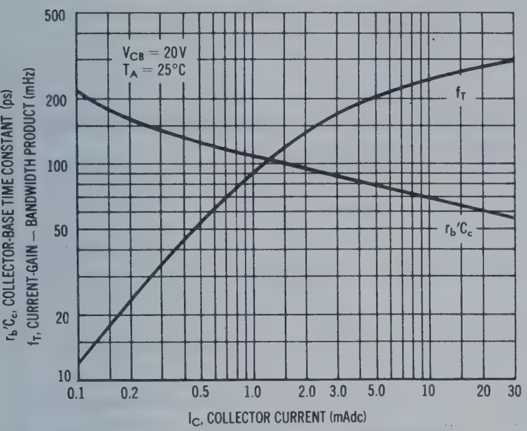


FIGURE 17 – CAPACITANCES

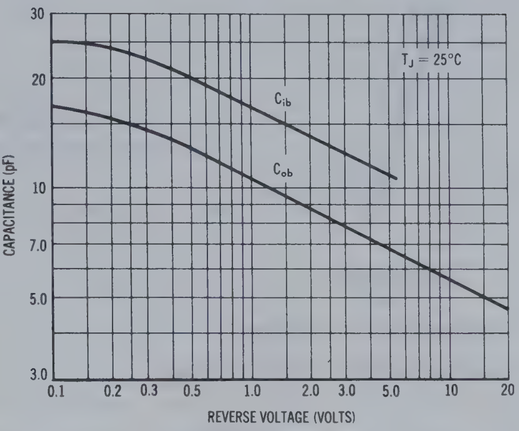
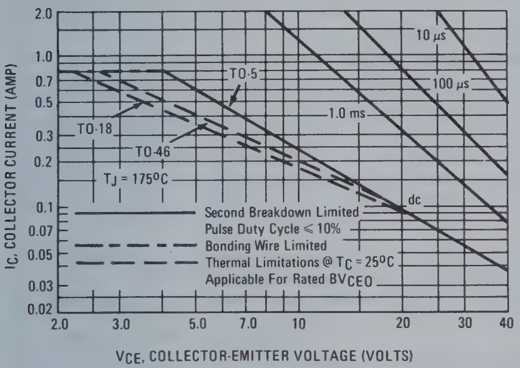


FIGURE 18 – ACTIVE-REGION SAFE OPERATING AREAS

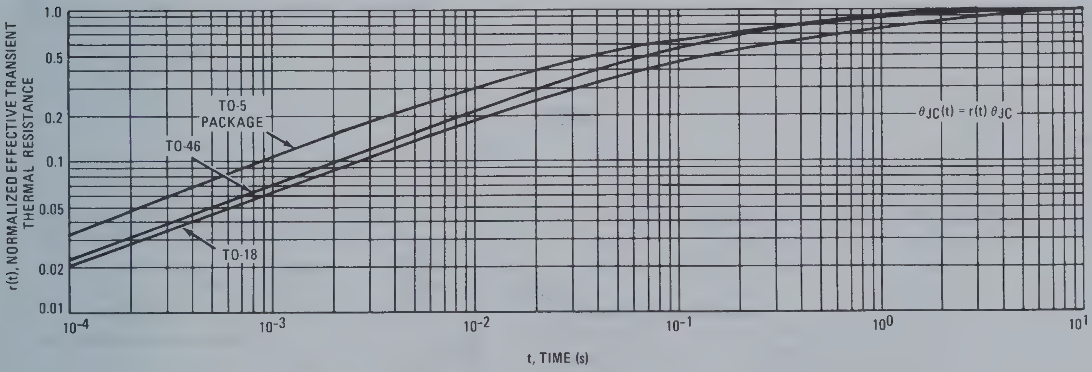


This graph shows the maximum I_C-V_{CE} limits of the device both from the standpoint of thermal dissipation (at 25°C case temperature), and secondary breakdown. For case temperatures other than 25°C, the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

For pulse applications, the maximum I_C-V_{CE} product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

FIGURE 19 – THERMAL RESPONSE



2N2223, A

For Specifications, See 2N2060 Data.

2N2224 (SILICON)

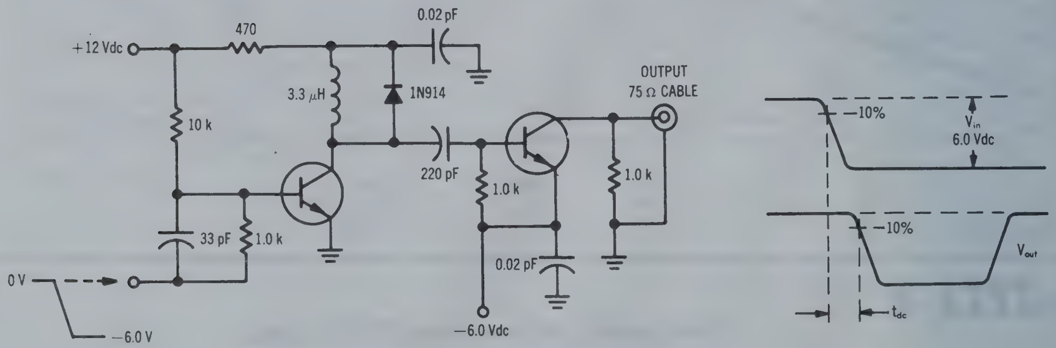
CASE 31
(TO-5)
Collector connected to case

NPN silicon annular transistor designed primarily for high speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current-Continuous	I_C	0.5	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.8 5.33	W mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 20	Watts mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1


+12 Vdc
470
0.02 pF
3.3 μH
1N914
OUTPUT
75 Ω CABLE
10 k
220 pF
1.0 k
1.0 k
33 pF
1.0 k
0 V
−6.0 V
0.02 pF
−6.0 Vdc
−10%
V_{in}
6.0 Vdc
−10%
V_{out}
t_{dc}

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	65	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector-Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	- -	0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	20 25 35 40	- - 115 120	-
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) (I_C = 80 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250 160	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	8.0	pF
Circuit Delay (Figure 1) (T_A = 25°C)	t_{dc}	-	15	ns
Circuit Delay - Total Change (Figure 1) (T_A = +10°C to T_A = +25°C)	Δt_{dc}	-	15	ns

(1) Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2.0%

2N2242 (SILICON)

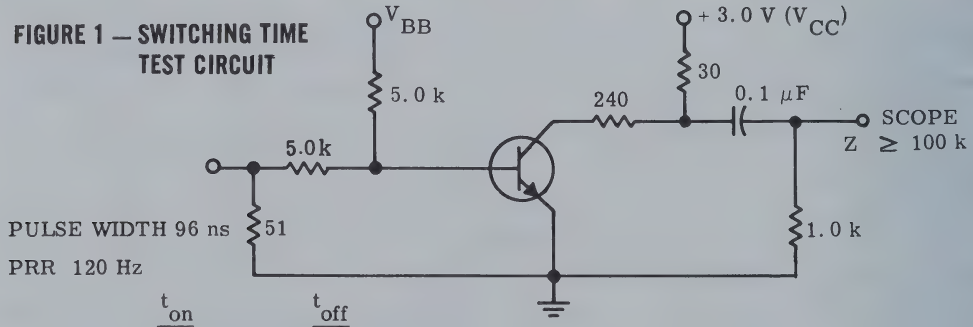
CASE 22
(TO-18)

NPN silicon annular transistors designed for high-speed, low-power saturated switching applications.

MAXIMUM RATINGS

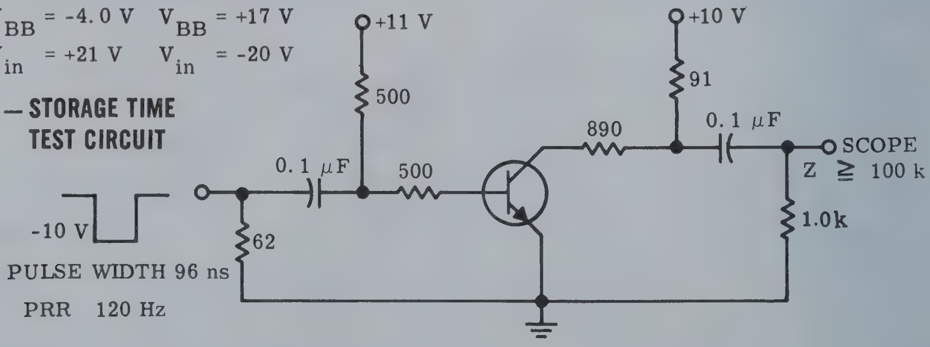
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	225	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.0	mWatts mW/°C
Junction Temperature — Operating	T_J	-65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — SWITCHING TIME TEST CIRCUIT


V_{BB}
5.0 k
5.0k
51
PULSE WIDTH 96 ns
PRR 120 Hz
+ 3.0 V (V_{CC})
30
240
0.1 μF
SCOPE
Z ≥ 100 k
1.0 k

t_{on}	t_{off}
V_{BB} = -4.0 V	V_{BB} = +17 V
V_{in} = +21 V	V_{in} = -20 V

FIGURE 2 — STORAGE TIME TEST CIRCUIT

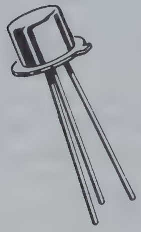

-10 V
PULSE WIDTH 96 ns
PRR 120 Hz
62
0.1 μF
+11 V
500
500
+10 V
91
890
0.1 μF
SCOPE
Z ≥ 100 k
1.0k

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 30 mAdc, I_E = 0)	BV_{CEO}	15	-	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 30 mAdc, R_{BE} = ≤ 10 ohms)	BV_{CER}	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 125°C)	I_{CEX}	-	10	μAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.1 15	μAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	h_{FE}	40 20	120 -	-
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55 to +125°C)	$V_{CE(sat)}$	- -	0.7 0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 125°C)	$V_{BE(sat)}$	- -	1.5 0.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Turn-On Time (Figure 1) (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = +2.0 Vdc, I_{B1} = 3.0 mAdc, I_C = 10 mAdc)	t_{on}	-	30	ns
Turn-Off Time (Figure 1) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	50	ns
Storage Time (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	-	25	ns

(1) Pulse Test: Pulse Wdith = 300 μs; Duty Cycle = ≤ 2%

2N2256, 2N2257 (SILICON)
2N2258 (GERMANIUM)
2N2259 (GERMANIUM)



CASE 22
(TO-18)

Collector connected to case

NPN silicon and PNP germanium mesa complementary transistors for high-speed non-saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2256 2N2257	2N2258 2N2259	Unit
Collector-Emitter Voltage	V_{CEO}	7.0	7.0	Vdc
Collector-Base Voltage	V_{CB}	7.0	7.0	Vdc
Emitter-Base Voltage	V_{EB}	1.0	1.0	Vdc
Collector Current-Continuous	I_C	100	100	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	300 2.0	150 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	1000 6.67	300 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	-65 to +100	°C

TRANSISTOR SELECTION CHART

TYPE	TYPE		h_{FE} @ $I_C = 25$ mA	
	NPN	PNP	20	40
2N2256	X		X	
2N2257	X			X
2N2258		X	X	
2N2259		X		X

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)		BV_{CES}	7.0	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	7.0	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	1.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	3.0	10	μAdc
(V_{CB} = 6 Vdc, I_E = 0, T_A = 65°C)			-	30	100	
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N2256, 2N2258	h_{FE}	17	30	-	-
	2N2257, 2N2259		40	50	-	
(I_C = 25 mAdc, V_{CE} = 1 Vdc)	2N2256, 2N2258		20	35	-	
	2N2257, 2N2259		40	55	-	
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N2256, 2N2257	$V_{BE(on)}$	-	0.70	0.8	Vdc
	2N2258, 2N2259		-	0.35	0.5	
(I_C = 25 mAdc, V_{CE} = 1 Vdc)	2N2256, 2N2257		-	0.8	0.9	
	2N2258, 2N2259		-	0.45	0.6	
Conduction Threshold Base-Emitter Voltage* (I_C = 200 μAdc, V_{CE} = 1 Vdc)	2N2256, 2N2257	V_T	0.5	-	-	Vdc
	2N2258, 2N2259		0.1	-	-	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	2N2258, 2N2259	f_T	250	320	-	MHz
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	2N2256, 2N2257		250	320	-	
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 4 MHz)	2N2256, 2N2257	C_{ob}	-	4.0	5.0	pF
	2N2258, 2N2259		-	4.0	8.0	
Base Resistance (I_E = 5 mAdc, V_{CB} = 2 Vdc, f = 300 MHz)	2N2256, 2N2257	r'_b	-	50	100	Ohms
	2N2258, 2N2259		-	75	125	
Turn-On Time	2N2256, 2N2257 See Fig. 1	t_{on}	-	3.0	7.0	ns
	2N2258, 2N2259 See Fig. 2		-	4.0	8.0	
Turn-Off Time	2N2256, 2N2257 See Fig. 1	t_{off}	-	4.0	7.0	ns
	2N2258, 2N2259 See Fig. 2		-	3.0	7.0	

*Base-to-emitter forward bias voltage at which transistor will be at the threshold of conduction; i.e. that base-to-emitter voltage at which the collector current is less than or equal to the specified amount under a given collector-to-emitter voltage condition.

FIGURE 1 — NPN SWITCHING TIME TEST CIRCUIT

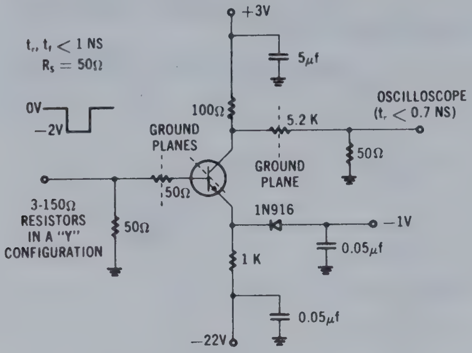

+3V
t_r, t_f < 1 NS
R_s = 50Ω
5μf
0V
−2V
100Ω
GROUND PLANES
5.2 K
OSCILLOSCOPE (t_r < 0.7 NS)
50Ω
GROUND PLANE
50Ω
3-150Ω RESISTORS IN A "Y" CONFIGURATION
50Ω
1N916
−1V
0.05μf
1 K
0.05μf
−22V

FIGURE 2 — PNP SWITCHING TIME TEST CIRCUIT

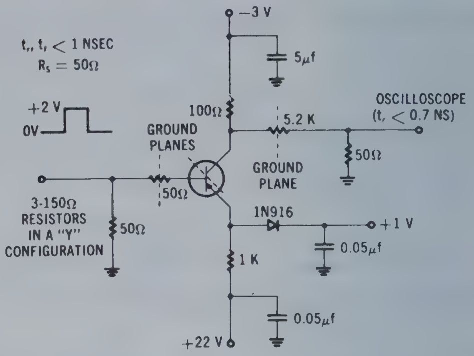

−3 V
t_r, t_f < 1 NSEC
R_s = 50Ω
5μf
+2 V
0V
100Ω
GROUND PLANES
5.2 K
OSCILLOSCOPE (t_r < 0.7 NS)
50Ω
GROUND PLANE
50Ω
3-150Ω RESISTORS IN A "Y" CONFIGURATION
50Ω
1N916
+1 V
0.05μf
1 K
0.05μf
+22 V

FIGURE 3 — CASCADE COMPLEMENTARY GATE

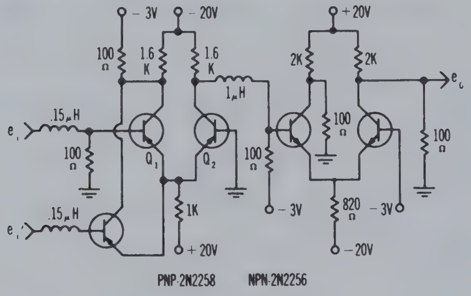

− 3V
− 20V
+ 20V
100 Ω
1.6 K
1.6 K
1μH
2K
2K
e_o
.15μH
e_i
100 Ω
Q_1
Q_2
100 Ω
100 Ω
100 Ω
.15μH
e_i
1K
− 3V
820 Ω
− 3V
+ 20V
− 20V
PNP-2N2258
NPN-2N2256

FIGURE 4 — CURRENT MODE INVERTER FOR USE WITH DIODE LOGIC PROPAGATION DELAY TIME 10 ns

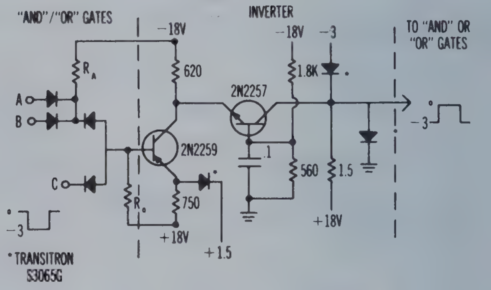

"AND"/"OR" GATES
INVERTER
−18V
−18V
−3
TO "AND" OR "OR" GATES
R_A
620
1.8K
*
2N2257
A
B
2N2259
.1
C
560
1.5
*
R_o
750
*
−3
+18V
+1.5
+18V
−3
* TRANSITRON S3065G

FIGURE 5 — CURRENT GAIN CHARACTERISTICS

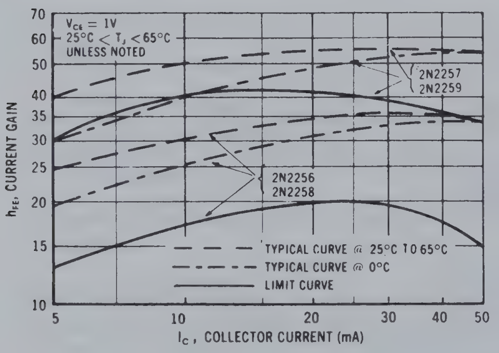
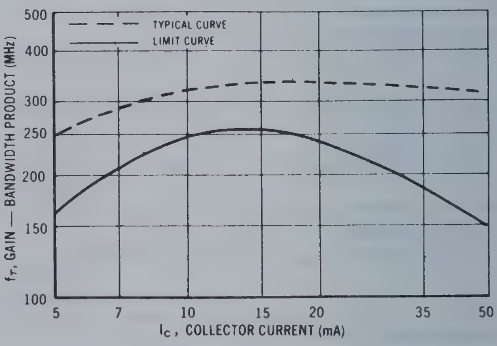


FIGURE 6 — CURRENT GAIN-BANDWITH PRODUCT CHARACTERISTICS



2N2273 (GERMANIUM)
2N2273 JAN

CASE 22
(TO-18)

Collector connected to case

High-frequency germanium PNP transistor, designed for military and high-reliability industrial as well as commercial VHF amplifier applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Volts
Collector-Emitter Voltage	V_{CES}	25	Volts
Collector-Emitter Voltage	V_{CEO}	15	Volts
Emitter-Base Voltage	V_{EB}	1.0	Volt
Collector Current	I_C	100	mA
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0	mW mW/°C
Junction Operating & Storage Temperature Range	T_J, T_{stg}	-65 to +100	°C

TABLE I — GROUP A INSPECTION (T_A = 25°C unless otherwise noted)

BOTH TYPES (LTPD applies to JAN 2N2273 only)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Visual and Mechanical Examination	2071	—	—	—	—	5
SUBGROUP 2						
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	10	μAdc	5
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	3001 Condition D	BV_{CBO}	25	—	Vdc	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	3026 Condition D	BV_{EBO}	1.0	—	Vdc	
Forward Current Transfer Ratio* (I_C = 1 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}*	20	75	—	
Collector-Emitter Breakdown Voltage (I_C = 200 μAdc, V_{BE} = 0)	3011 Condition C	BV_{CES}	25	—	Vdc	
Small-Signal Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 10 MHz)	3306	h_{fe}	20	28	dB	

* Applies to MIL unit only

TABLE I — GROUP A INSPECTION (continued)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 3						
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	3236	C_{ob}	—	3.5	pF	10
Base Spreading Resistance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 250 MHz)	3266	r_b'	—	250	ohms	
Small-Signal Forward Current Transfer Ratio* (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 100 MHz)	3306	h_{fe}*	2.5	—	—	
Noise Figure* (V_{CB} = 10 Vdc, I_C = 1 mAdc, f = 10 MHz, R_G = 50 ohms)	3246	NF*	—	12	dB	

STANDARD UNIT ONLY

Examination or Test	Symbol	Min	Max	Unit	LTPD
Emitter-Base Leakage Current (V_{EB} = 0.5 Vdc, I_C = 0)	I_{EBO}	—	100	μAdc	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CEO}	15	—	Vdc	
Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	150	—	—
Real Part of Small-Signal Short-Circuit Input Impedance (V_{CE} = 10 Vdc, I_C = 1 mAdc, f = 250 MHz)	$Re(h_{ie})$	50	250	ohms	
Power Gain (See Figure 1) (V_{CE} = 9 Vdc, I_C = 1 mAdc, f = 30 MHz)	G_{PE}	10	30	dB	

* Applies to MIL unit only

TABLE II — GROUP B INSPECTION — JAN 2N2273 only

(T_A = 25°C unless otherwise noted)

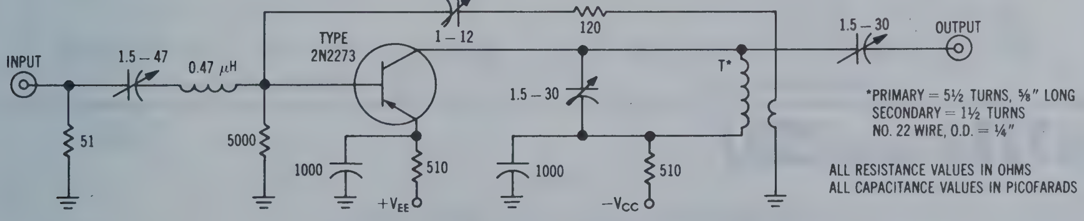
Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Physical Dimensions	2066	—	—	—	—	10
SUBGROUP 2						
Solderability	2026	—	—	—	—	10
Temperature Cycling ($T_{high} = 100^{+3}_{-0}$ °C; 10 cycles)	1051 Condition B	—	—	—	—	
Thermal Shock (Glass Strain)	1056 Condition A	—	—	—	—	
Moisture Resistance	1021	—	—	—	—	
End Points: (Subgroups 2, 3, 5, 6, 7)						
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	20	μAdc	
DC Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	15	—	—	

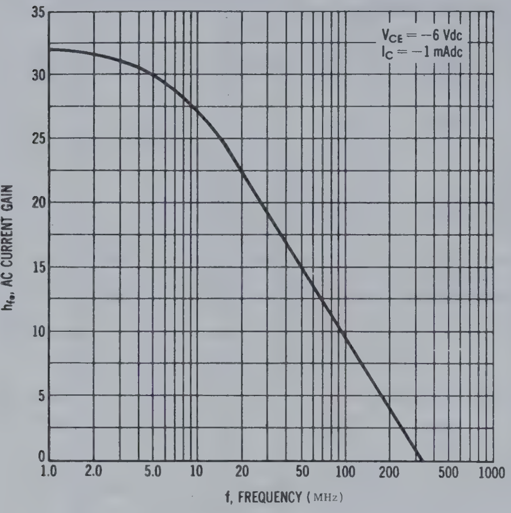
TABLE II — GROUP B INSPECTION (continued)

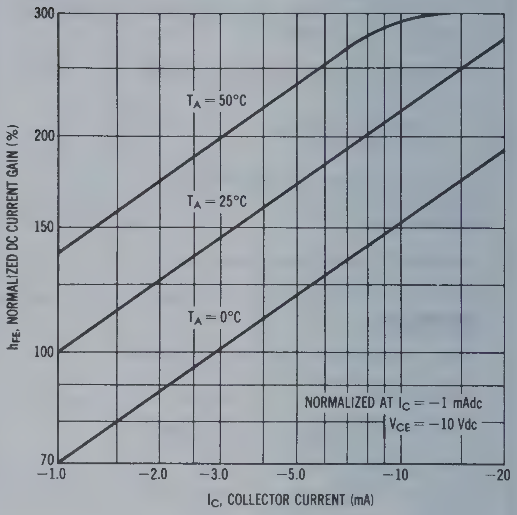
Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 3						10
Shock (500 G, 1 msec, 5 blows each orientation: Y_1, Y_2, X_1 and Z_1)	2016 Nonoperating	—	—	—	—	
Vibration, Variable Frequency (10 G)	2056	—	—	—	—	
Constant Accelerating (10, 000 G)	2006	—	—	—	—	
End Points: Same as Subgroup 2						
SUBGROUP 4						
Lead Fatigue (Note 1)	2036 Condition E	--	—	—	—	10
SUBGROUP 5						10
High Temperature Operation (Note 2) ($T_A = 70^{+3}_{-0}$ °C)		—	—	—	—	
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036	I_{CBO}	—	100	μ Adc	
Low Temperature Operation (Note 2) (T_A = -55±3°C)		—	—	—	—	
Forward Current Transfer Ratio (V_{CE} = 10 Vdc, I_C = 1 mAdc)	3076	h_{FE}	8.0	—	—	
Salt Atmosphere (Corrosion)	1041	—	—	—	--	
End Points: Same as Subgroup 2						
SUBGROUP 6						
High Temperature Life ($T_A = 100^{+5}_{-0}$ °C)	1031 (Nonoperating)	—	—	—	—	λ = 10
End Points: Same as Subgroup 2						
SUBGROUP 7						
Steady State Operation Life (V_{CB} = 10 Vdc, P_C = 60 mW, $T_A = 55^{+3}_{-0}$ °C)	1026	—	—	—	—	λ = 10
End Points: Same as Subgroup 2						

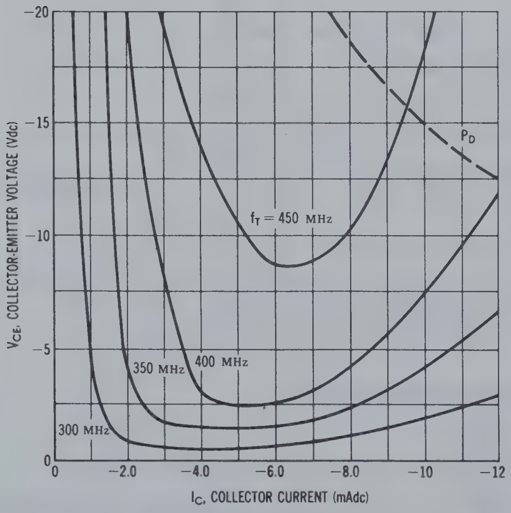
Note 1. Rejects from prior electrical tests from the same lot may be used for this test.
Note 2. Test measurement shall be made after thermal equilibrium has been reached at the temperature specified.

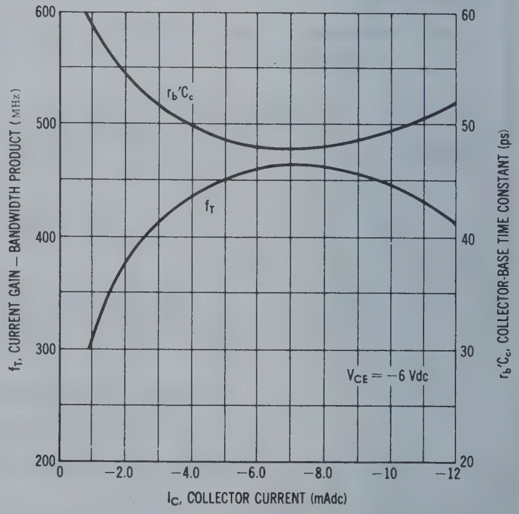
FIGURE 1 — 30 MHz POWER GAIN TEST CIRCUIT


INPUT
51
1.5 – 47
0.47 μH
5000
TYPE
2N2273
1000
510
+VEE
1 – 12
120
1.5 – 30
1000
510
–VCC
T*
1.5 – 30
OUTPUT
*PRIMARY = 5½ TURNS, ⅝" LONG
SECONDARY = 1½ TURNS
NO. 22 WIRE, O.D. = ¼"
ALL RESISTANCE VALUES IN OHMS
ALL CAPACITANCE VALUES IN PICOFARADS


AC CURRENT GAIN versus FREQUENCY


VARIATION IN DC GAIN versus COLLECTOR CURRENT


CONTOURS OF CURRENT GAIN — BANDWIDTH PRODUCT


f_T AND $r_b'C_c$ versus COLLECTOR CURRENT

2N2285 thru 2N2287

For Specifications, See 2N1651 Data.

2N2288, 2N2289 (GERMANIUM)
2N2290

PNP GERMANIUM POWER SWITCHING TRANSISTORS

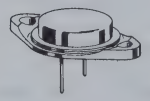
. . . designed for fast-switching applications requiring low saturation voltage and excellent collector-emitter sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.5 Vdc (Max) @ I_C = 5.0 Adc
  $V_{BE(sat)}$ = 1.0 Vdc (Max) @ I_C = 5.0 Adc

10 AMPERE

PNP ADE GERMANIUM POWER TRANSISTORS

40-120 VOLTS
70 WATTS



MAXIMUM RATINGS

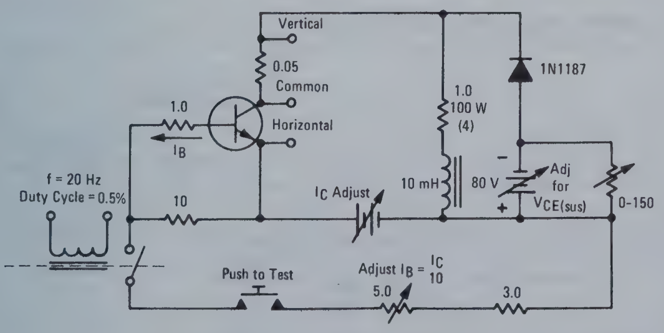
Rating	Symbol	2N2288	2N2289	2N2290	Unit
*Collector-Emitter Voltage (R_{BE} = 100 Ohms)	V_{CER}	40	80	120	Vdc
*Collector-Base Voltage	V_{CB}	40	80	120	Vdc
*Emitter-Base Voltage	V_{EB}	← 0.75 →			Vdc
*Collector Current - Continuous	I_C	← 10 →			Adc
Base Current - Continuous	I_B	← 3.0 →			Adc
Total Device Dissipation @ T_C = 25°C *Derate above 25°C	P_D	← 70 → 0.833			Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →			°C

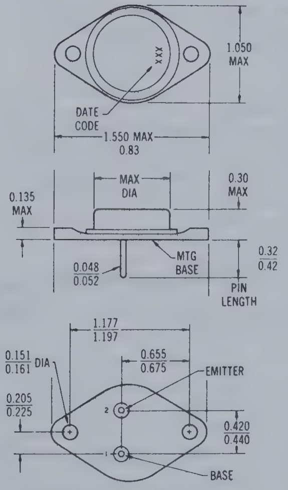
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	°C/W

*Indicates JEDEC Registered Data.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
0.05
Common
1.0
Horizontal
I_B
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
1.0
100 W
(4)
10 mH
1N1187
80 V
Adj for $V_{CE(sus)}$
0-150
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0


XXX
DATE CODE
1.050 MAX
1.550 MAX
0.83
MAX DIA
0.135 MAX
0.30 MAX
0.048
0.052
MTG BASE
0.32
0.42
PIN LENGTH
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
1
0.420
0.440
BASE

Collector Connected to Case

CASE 11A
(TO-3)

Except Pin Diameter

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N2288 2N2289 2N2290	BV_{CEO}	30 50 70	- - -	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 5.0 Adc)	2N2288 2N2289 2N2290	$V_{CE(sus)}$	30 50 70	- - -	Vdc
*Collector-Emitter Breakdown Voltage (I_C = 50 mAdc, R_{BE} = 100 Ohms)	2N2288 2N2289 2N2290	BV_{CER}	40 80 120	- - -	Vdc
*Collector Cutoff Current (V_{CE} = 15 Vdc, I_B = 0) (V_{CE} = 25 Vdc, I_B = 0) (V_{CE} = 35 Vdc, I_B = 0)	2N2288 2N2289 2N2290	I_{CEO}	- - -	50 50 50	mAdc
*Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C) (V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C) (V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C)	2N2288 2N2289 2N2290	I_{CEX}	- - -	35 35 35	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0) *(V_{CB} = 40 Vdc, I_E = 0) *(V_{CB} = 80 Vdc, I_E = 0) *(V_{CB} = 120 Vdc, I_E = 0)	All Types 2N2288 2N2289 2N2290	I_{CBO}	- - - -	200 5.0 5.0 5.0	μAdc mAdc
Emitter Cutoff Current (V_{EB} = 0.75 Vdc, I_C = 0)		I_{EBO}	-	25	mAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
*DC Current Gain (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	20 20	- 60	-
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{BE(sat)}$	-	1.0	Vdc

SMALL-SIGNAL CHARACTERISTICS

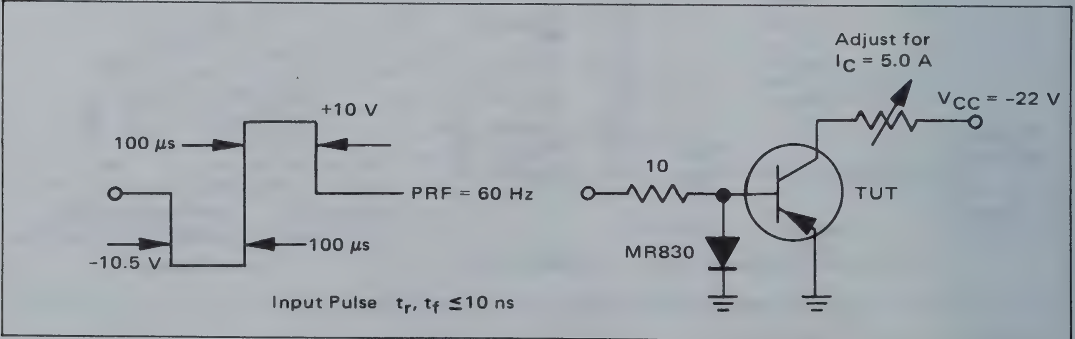
Characteristic	Symbol	Min	Max	Unit
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 14 Vdc, f = 1.0 kHz) (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)	h_{fe}	25 15	100 -	-

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Rise Time	I_C = 5.0 Adc, I_{B1} = I_{B2} = 1.0 Adc) (See Figure 2)	t_r	-	5.0	μs
Storage Time		t_s	-	7.0	μs
Fall Time		t_f	-	8.0	μs

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N2291, 2N2292 (GERMANIUM)
2N2293

PNP GERMANIUM POWER SWITCHING TRANSISTORS

. . . designed for fast switching applications requiring low saturation voltage and excellent collector-emitter sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages —
  $V_{CE(sat)} = 0.5$ Vdc @ $I_C = 5.0$ Adc
  $V_{BE(sat)} = 1.0$ Vdc @ $I_C = 5.0$ Adc

MAXIMUM RATINGS

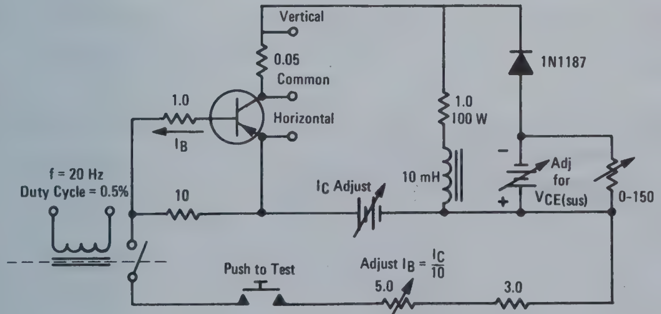
Rating	Symbol	2N2291	2N2292	2N2293	Unit
*Collector-Emitter Voltage	V_{CEO}	30	50	70	Vdc
*Collector-Base Voltage	V_{CB}	40	80	120	Vdc
*Emitter-Base Voltage	V_{EB}	← 1.5 →			Vdc
*Collector Current - Continuous	I_C	← 10 →			Adc
*Base Current - Continuous	I_B	← 3.0 →			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	← 70 → ← 0.83 →			Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	°C/W

*Indicates JEDEC Registered Data.

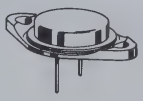
FIGURE 1 — SUSTAINING VOLTAGE TEST CIRCUIT

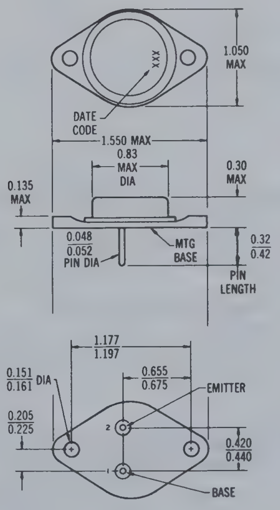

Vertical
0.05
Common
1.0
Horizontal
I_B
1N1187
1.0
100 W
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
10 mH
−
+
Adj for $V_{CE(sus)}$
0-150
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0

10 AMPERE

PNP ADE GERMANIUM POWER TRANSISTORS

40-120 VOLTS
70 WATTS




XXX
1.050 MAX
DATE CODE
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
0.048
0.052
PIN DIA
MTG BASE
0.32
0.42
PIN LENGTH
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
1
0.420
0.440
BASE

Collector Connected to Case

CASE 11A
(TO-3)

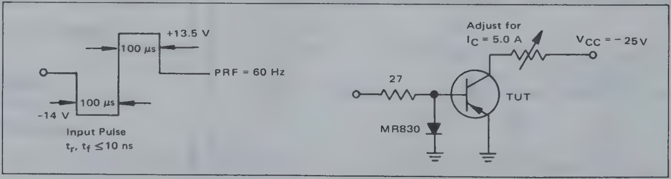
Except Pin Diameter

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0) 2N2291	BV_{CEO}	30	-	Vdc
2N2292		50	-	
2N2293		70	-	
*Collector-Emitter Sustaining Voltage (See Figure 1) *(I_C = 500 mAdc) 2N2291	$V_{CE(sus)}$	30	-	Vdc
2N2292		50	-	
2N2293		70	-	
**(I_C = 5.0 Adc) 2N2291		25	-	
2N2292		50	-	
2N2293		70	-	
*Collector-Emitter Breakdown Voltage (I_C = 50 mAdc, R_{BE} = 100 ohms) 2N2291	BV_{CER}	40	-	Vdc
2N2292		80	-	
2N2293		120	-	
*Collector Cutoff Current (V_{CE} = 15 Vdc, I_B = 0) 2N2291	I_{CEO}	-	50	mAdc
(V_{CE} = 25 Vdc, I_B = 0) 2N2292		-	50	
(V_{CE} = 35 Vdc, I_B = 0) 2N2293		-	50	
*Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C) 2N2291	I_{CEX}	-	35	mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C) 2N2292		-	35	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C) 2N2293		-	35	
Collector Cutoff Current *(V_{CB} = -2.0 Vdc, I_E = 0) All Types	I_{CBO}	-	200	µAdc
*(V_{CB} = 40 Vdc, I_E = 0) 2N2291		-	5.0	mAdc
*(V_{CB} = 80 Vdc, I_E = 0) 2N2292		-	5.0	
*(V_{CB} = 120 Vdc, I_E = 0) 2N2293		-	5.0	
Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)	I_{EBO}	-	50	mAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc)	h_{FE}	40	-	-
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		50	120	
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{BE(sat)}$	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 14 Vdc, f = 1.0 kHz)	h_{fe}	50	200	-
(I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)		15	-	
SWITCHING CHARACTERISTICS				
Rise Time (I_C = 5.0 Adc, I_{B1} = I_{B2} = 0.5 Adc) (See Figure 2)	t_r	-	7.0	µs
Storage Time	t_s	-	10	µs
Fall Time	t_f	-	8.0	µs

*Indicates JEDEC Registered Data.
**Motorola guarantees this data in addition to the JEDEC Registered Data Shown.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N2303 (SILICON)

For Specifications, See 2N722 Data.

2N2322 thru 2N2326 (SILICON)

CASE 31(2)
(TO-5)

All-diffused PNPN thyristors designed for gating operation in mA/μA signal or detection circuits.

MAXIMUM RATINGS*(T_J = 125°C unless otherwise noted, R_{GK} = 1000 ohms)

Rating		Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1)	2N2322	$V_{RSM(rep)}$	25	Volts
	2N2323		50	
	2N2324		100	
	2N2325		150	
	2N2326		200	
Non-Repetitive Peak Reverse Blocking Voltage ($t < 5.0$ ms)	2N2322	$V_{RSM(non\text{-}rep)}$	40	Volts
	2N2323		75	
	2N2324		150	
	2N2325		225	
	2N2326		300	
Forward Current RMS (All Conduction Angles)		$I_{T(RMS)}$	1.6	Amp
Peak Surge Current (One-Half Cycle, 60 Hz) No Repetition Until Thermal Equilibrium is Restored		I_{TSM}	15	Amp
Peak Gate Power — Forward		P_{GM}	0.1	Watt
Average Gate Power — Forward		$P_{G(AV)}$	0.01	Watt
Peak Gate Current — Forward		I_{GM}	0.1	Amp
Peak Gate Voltage — Forward		V_{GFM}	6.0	Volts
Reverse		V_{GRM}	6.0	
Operating Junction Temperature Range		T_J	-65 to +125	°C
Storage Temperature Range		T_{stg}	-65 to +150	°C
Lead Solder Temperature (> 1/16" from case, 10 sec. max)		-	+230	°C

* JEDEC Registered Values

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1)	V_{DRM}			Volts
2N2322		25*	-	
2N2323		50*	-	
2N2324		100*	-	
2N2325		150*	-	
2N2326		200*	-	
Peak Reverse Blocking Current (Rated V_{DRM}, T_J = 125°C)	I_{RRM}	-	100*	µA
Peak Forward Blocking Current (Rated V_{DRM}, T_J = 125°C)	I_{DRM}	-	100*	µA
Forward "On" Voltage	V_T			Volts
(I_T = 1.0 A Peak)		-	1.5	
(I_T = 3.14 A Peak, T_C = 85°C)		-	2.0*	
Gate Trigger Current (Note 2)	I_{GT}			µA
(Anode Voltage = 6.0 Vdc, R_L = 100 ohms)		-	200	
(Anode Voltage = 6.0 Vdc, R_L = 100 ohms, T_C = -65°C)		-	350*	
Gate Trigger Voltage	V_{GT}			Volts
(Anode Voltage = 6.0 V, R_L = 100 ohms)		-	0.8	
(Anode Voltage = 6.0 V, R_L = 100 ohms, T_C = -65°C)		-	1.0*	
(V_{DRM} = Rated, R_L = 100 ohms, T_J = 125°C)		0.1*	-	
Holding Current	I_H			mA
(Anode Voltage = 6.0 V)		-	2.0	
(Anode Voltage = 6.0 V, T_C = -65°C)		-	3.0*	
(Anode Voltage = 6.0 V, T_C = 125°C)		0.15*	-	
Turn-On Time	t_{gt}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_q			

* JEDEC Registered Values

Notes: 1. V_{RSM} and V_{DRM} can be applied for all types on a continuous dc basis without incurring damage.

2. R_{GK} current is not included in measurement.

Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 — CASE TEMPERATURE vs CURRENT

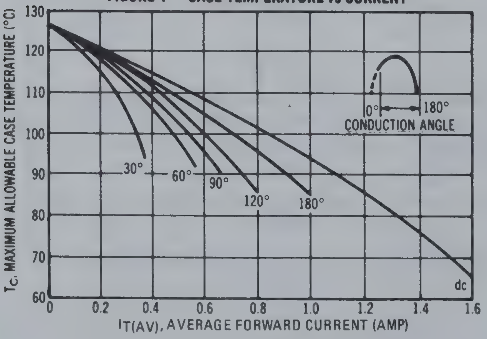
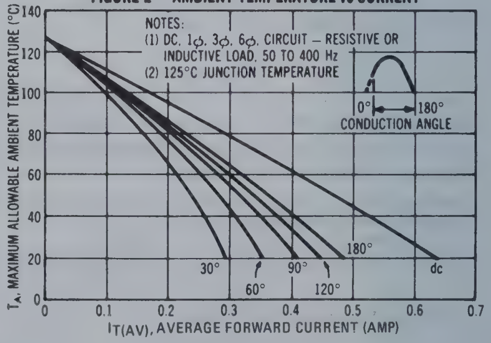
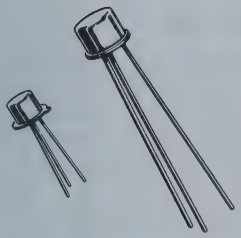


FIGURE 2 — AMBIENT TEMPERATURE vs CURRENT



2N2330 (SILICON)
2N2331



CASE 22
(TO-18)
2N2331

CASE 31
(TO-5)
2N2330

Collector connected to case

NPN silicon annular Star transistors for low-level DC/AC chopper applications.

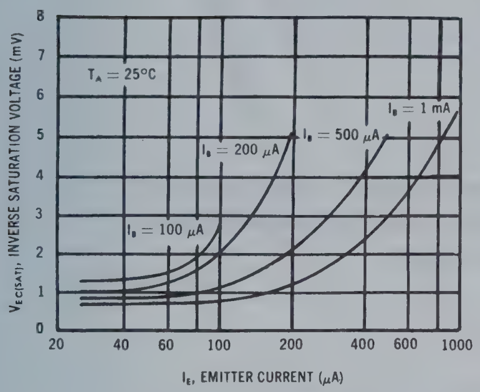
MAXIMUM RATINGS

Rating	Symbol	2N2330 (TO-5)	2N2331 (TO-18)	Unit
Collector-Emitter Voltage	V_{CEO}	20	20	Vdc
Collector-Base Voltage	V_{CB}	30	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Collector Current	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	0.8 5.33	0.5 3.33	Watt $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	3.0 20	1.8 12	Watts $mW/^oC$
Operating Junction Temperature Range	T_J	-65 to +175		^oC
Storage Temperature Range	T_{stg}	-65 to +200		^oC

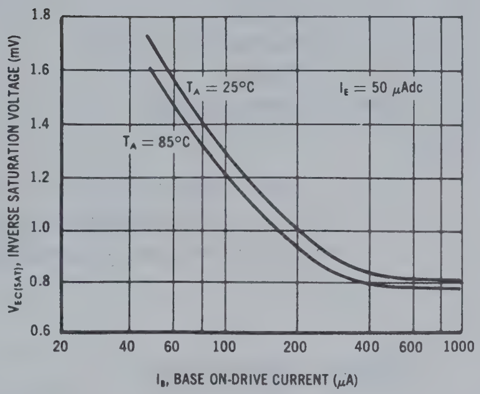
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 4.5 Vdc, I_E = 0)	I_{CBO}	-	1.0	nAdc
Emitter Cutoff Current (V_{BE} = 4.5 Vdc)	I_{EBO}	-	5.0	nAdc
Offset Current (V_{BC} = 2 Vdc, V_{CE} = 0, T_A = 25°C)	$I_{(off)}$	-	1	nAdc
(V_{BC} = 2 Vdc, V_{CE} = 0, T_A = 85°C)		-	10	
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc)	h_{FE}	50	-	-
Offset Voltage (I_B = 200 μAdc, I_E = 0)	$V_{(off)}$	-	0.75	mVdc
Inverse Saturation Voltage (I_B = 200 μAdc, I_E = 50 μAdc)	$V_{EC(sat)}$	-	3.0	mVdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 1 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	f_T	100	-	MHz
Output Capacitance (V_{CB} = 2 Vdc, I_E = 0)	C_{ob}	-	10	pF
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0)	C_{ib}	-	20	pF

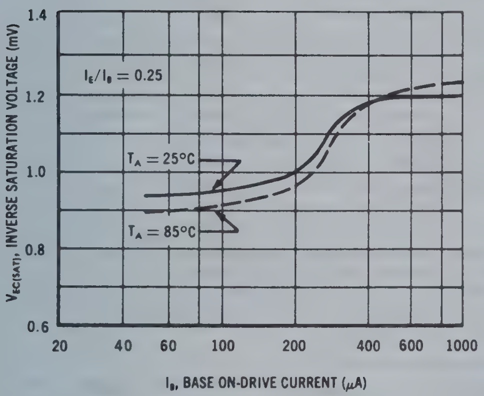
INVERSE SATURATION VOLTAGE
versus
EMITTER CURRENT



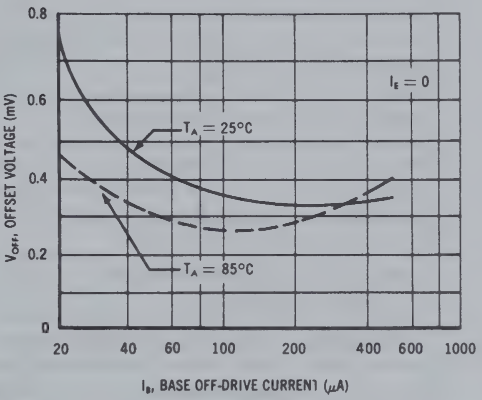
INVERSE SATURATION VOLTAGE
versus
BASE CURRENT



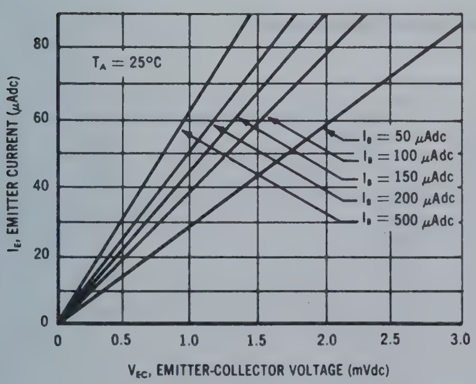
INVERSE SATURATION VOLTAGE
versus
BASE CURRENT



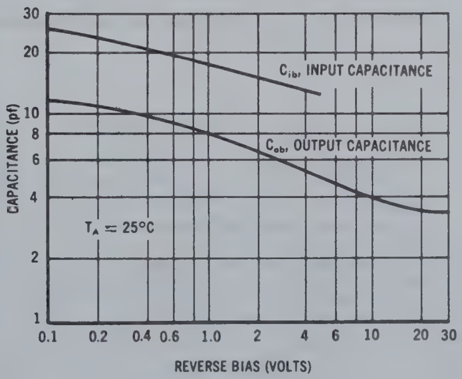
OFFSET VOLTAGE
versus
BASE CURRENT



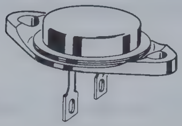
INVERSE
SATURATION
CHARACTERISTICS



OUTPUT CAPACITANCE versus COLLECTOR-BASE VOLTAGE
and
INPUT CAPACITANCE versus EMITTER-BASE VOLTAGE



2N2357 thru 2N2359 (Germanium)



CASE 161
(TO-41)
Collector Connected to Case

PNP Germanium power transistors designed for very high-current switching applications requiring low saturation voltages, fast switching times and good safe operating area.

MAXIMUM RATINGS

Rating	Symbol	2N2357	2N2358	2N2359	Unit
Collector-Emitter Voltage	V_{CEO}	30	60	80	Vdc
Collector-Base Voltage	V_{CB}	60	100	120	Vdc
Emitter-Base Voltage	V_{EB}	←	2.5	→	Vdc
Collector Current - Continuous	I_C	←	50	→	Adc
Base Current - Continuous	I_B	←	10	→	Adc
Total Device Dissipation @ T_C = 25° C Derate above 25° C	P_D	←	170 2.0	→	Watts W/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +110	→	° C

THERMAL CHARACTERISTICS

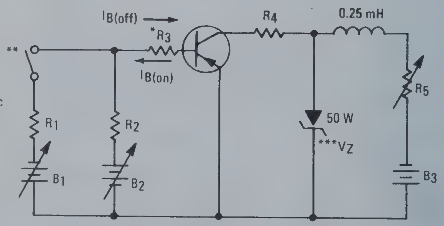
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	° C/W

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT

R_1 = 1.0 Ohm, 20 Watts
R_2 = 10 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 2.0 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc

*Not required if current probe is used to read I_{B1}
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum.



2N2357 thru 2N2359 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N2357	BV_{CEO}	30	-	-	Vdc
	2N2358		60	-	-	
	2N2359		80	-	-	
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 50 Adc)	2N2357	$V_{CE(sus)}$	35	-	-	Vdc
	2N2358		40	-	-	
	2N2359		45	-	-	
Collector -Emitter Cutoff Current (V_{CE} = 60 Vdc, V_{BE} = 0	2N2357	I_{CES}	-	-	50	mAdc
(V_{CE} = 100 Vdc, V_{BE} = 0)	2N2358		-	-	50	
(V_{CE} = 120 Vdc, V_{BE} = 0)	2N2359		-	-	50	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	-	200	μAdc
Collector-Emitter Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2357	I_{CEX}	-	-	5.0	mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2358		-	-	5.0	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2359		-	-	5.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100° C) (+0, -3.0° C)	2N2357		-	-	35	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100° C) (+0, -3.0° C)	2N2358		-	-	35	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100° C) (+0, -3.0° C)	2N2359		-	-	35	
Emitter Cutoff Current (V_{EB} = 2.5 Vdc, I_C = 0)		I_{EBO}	-	-	50	mAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 20 Adc, V_{CE} = 1.5 Vdc)		h_{FE}	30	-	90	-
(I_C = 50 Adc, V_{CE} = 1.5 Vdc)			15	-	-	
Collector-Emitter Saturation Voltage (I_C = 50 Adc, I_B = 5.0 Adc)		$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 50 Adc, I_B = 5.0 Adc)		$V_{BE(sat)}$	-	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)		h_{fe}	20	-	-	-
SWITCHING CHARACTERISTICS						
Rise Time	(V_{CC} = -28 Vdc, I_C = 50 Adc, I_{B1} = 5.0 Adc, I_{B2} = 3.0 Adc) (See Figure 3)	t_r	-	12	-	μs
Storage Time		t_s	-	5.0	-	μs
Fall Time		t_f	-	6.0	-	μs

FIGURE 2 – SWITCHING TIMES

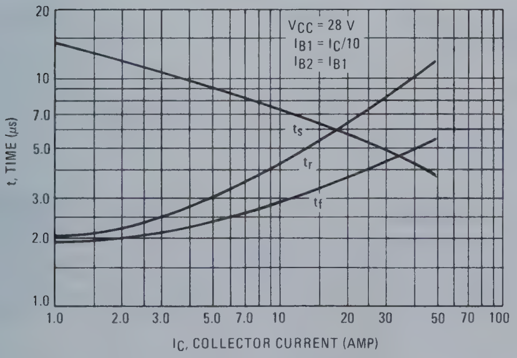
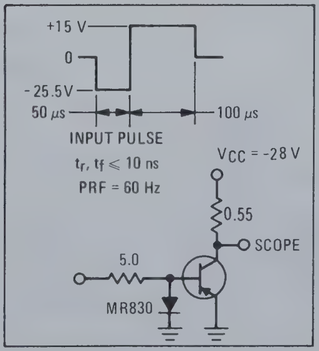


FIGURE 3 – SWITCHING TIME TEST CIRCUIT



2N2368 (SILICON)

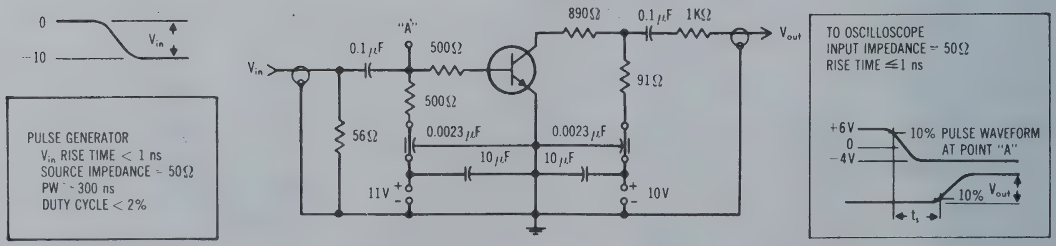
CASE 22
(TO-18)
Collector connected to case

NPN silicon annular transistor designed for high-speed, low-level, saturated-switching application.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	1.2 6.85	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT


0
−10
V_{in}
PULSE GENERATOR
V_{in} RISE TIME < 1 ns
SOURCE IMPEDANCE = 50Ω
PW ≈ 300 ns
DUTY CYCLE < 2%
V_{in}
0.1 μF
"A"
500Ω
500Ω
56Ω
0.0023 μF
10 μF
11V
+
-
890Ω
0.1 μF
1KΩ
V_{out}
91Ω
0.0023 μF
10 μF
+
-
10V
TO OSCILLOSCOPE
INPUT IMPEDANCE = 50Ω
RISE TIME ≤ 1 ns
+6V
0
−4V
10% PULSE WAVEFORM AT POINT "A"
10%
V_{out}
t_s

ELECTRICAL CHARACTERISTICS ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage [(1)] (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	15	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.5	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 — —	 0.4 30	μAdc
ON CHARACTERISTICS				
DC Current Gain [(1)] (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 2.0 Vdc)	h_{FE}	 20 10 10	 60 — —	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	—	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.7	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	—	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	4.0	pF
Storage Time (Figure 1) (I_C = I_{B1} = 10 mAdc, I_{B2} = -10 mAdc)	t_s	—	10	ns
Turn-On Time (Figure 2) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = -1.5 mAdc)	t_{on}	—	12	ns
Turn-Off Time (Figure 2) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = -1.5 mAdc)	t_{off}	—	15	ns

(1) Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%

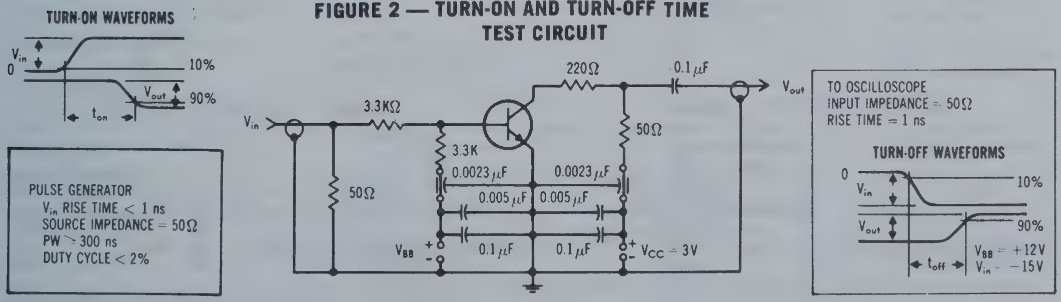

TURN-ON WAVEFORMS
V_{in}
0
10%
V_{out}
90%
t_{on}
PULSE GENERATOR
V_{in} RISE TIME < 1 ns
SOURCE IMPEDANCE = 50Ω
PW ≈ 300 ns
DUTY CYCLE < 2%
V_{in}
3.3KΩ
50Ω
3.3K
0.0023 μF
0.005 μF
0.1 μF
V_{BB}
220Ω
0.1 μF
50Ω
0.0023 μF
0.005 μF
0.1 μF
V_{CC} = 3V
V_{out}
TO OSCILLOSCOPE
INPUT IMPEDANCE = 50Ω
RISE TIME = 1 ns
TURN-OFF WAVEFORMS
0
V_{in}
10%
V_{out}
90%
t_{off}
V_{BB} = +12V
V_{in} = −15V

FIGURE 2 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

2N2369 (SILICON)
2N3227

CASE 22
(TO-18)
Collector connected to case

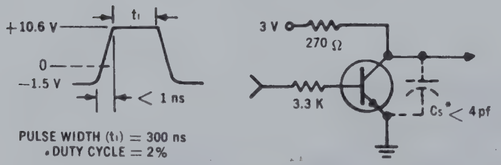
NPN silicon annular transistors for low-current, high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Emitter Voltage 2N2369 2N3227	V_{CEO}	15 20	Vdc
Emitter-Base Voltage 2N2369 2N3227	V_{EB}	4.5 6.0	Vdc
Collector Current (10 μsec pulse)	$I_{C(Peak)}$	500	mA
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	1.2 6.85	Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

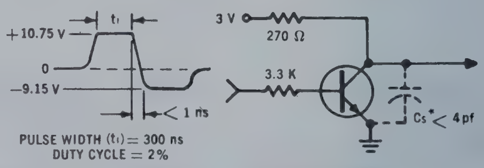
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — t_{on} CIRCUIT — 10 mA


+10.6 V
t₁
0
−1.5 V
< 1 ns
3 V
270 Ω
3.3 K
Cs* < 4 pf

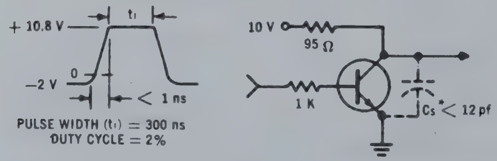
PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2%

FIGURE 3 — t_{off} CIRCUIT — 10 mA


+10.75 V
t₁
0
−9.15 V
< 1 ns
3 V
270 Ω
3.3 K
Cs* < 4 pf

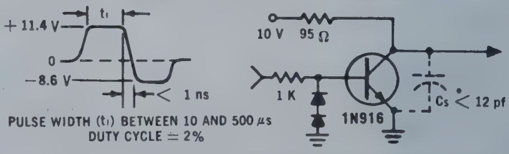
PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2%

FIGURE 2 — t_{on} CIRCUIT — 100 mA


+ 10.8 V
t₁
0
−2 V
< 1 ns
10 V
95 Ω
1 K
Cs* < 12 pf

PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2%

FIGURE 4 — t_{off} CIRCUIT — 100 mA


+ 11.4 V
t₁
0
−8.6 V
< 1 ns
10 V
95 Ω
1 K
1N916
Cs* < 12 pf

PULSE WIDTH (t_1) BETWEEN 10 AND 500 μs
DUTY CYCLE = 2%

* Total shunt capacitance of test jig and connectors.

2N2369, 2N3227 (continued)

ELECTRICAL CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Collector Cutoff Current			I_{CBO}			μAdc
(V_{CB} = 20 Vdc)	2N2369			—	0.4	
	2N3227			—	0.2	
(V_{CB} = 20 Vdc, T_A = 150°C)	2N2369			—	30	
	2N3227			—	50	
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)	2N3227		I_{CEX}	—	0. 2	μAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)	2N3227		I_{BL}	—	0.5	μAdc
Collector-Base Breakdown Voltage (I_C = 10μ Adc, I_B = 0)			BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage			BV_{EBO}			Vdc
(I_E = 10μ Adc, I_C = 0)	2N2369			4.5	—	
	2N3227			6.0	—	
Collector-Emitter Breakdown Voltage (1)			BV_{CEO}			Vdc
(I_C = 10 mAdc)	2N2369			15	—	
	2N3227			20	—	
Collector-Emitter Voltage (I_C = 10μ Adc, I_B = 0)			BV_{CES}	40	—	Vdc
Collector-Emitter Saturation Voltage (1)			$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	Both Types	11,13		—	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3227			—	0.45	
Base-Emitter Saturation Voltage (1)			$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	Both Types	13		0.70	0.85	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3227			0.8	1.4	
DC Current Gain (1)			h_{FE}			—
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N2369			40	120	
	2N3227	12		100	300	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	2N2369			20	—	
	2N3227	12		40	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3227	12		30	—	
(I_C = 100 mAdc, V_{CE} = 2 Vdc)	2N2369			20	—	
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)			h_{fe}	5.0	—	—
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)		5	C_{ob}	—	4. 0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 140 kHz)	2N3227		C_{ib}		4.0	pF
Storage Time (I_C = I_{B1} = I_{B2} = 10 mA)		10	t_s	—	13	ns
Turn-On Time (I_C = 10 mA, I_{B1} = 3 mA, V_{CC} = 3 V, $V_{EB(off)}$ = 1. 5 Vdc)		1,6	t_{on}	—	12	ns
Turn-Off Time (I_C = 10 mA, I_{B1} = 3 mA, I_{B2} = 1.5 mA, V_{CC} = 3 V)		3,6	t_{off}	—	18	ns
Total Control Charge (I_C = 10 mA, I_B = 1 mA, V_{CC} = 3 V)	2N3227	7,8	Q_T	—	50	pC
Delay Time — V_{CC} = 10 V, $V_{EB(off)}$ = 2 Vdc, I_C = 100 mA, I_{B1} = 10 mA	2N3227	2,6	t_d	—	5. 0	ns
Rise Time			t_r	—	18	ns
Storage Time — V_{CC} = 10 V, I_C = 100 mA, I_{B1} = I_{B2} = 10 mA	2N3227	4,6	t_s	—	13	ns
Fall Time			t_f	—	15	ns

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

FIGURE 5 – JUNCTION CAPACITANCE VARIATIONS

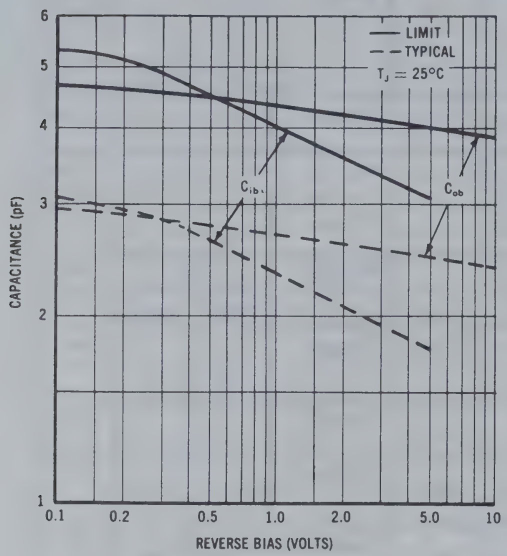


FIGURE 6 – TYPICAL SWITCHING TIMES

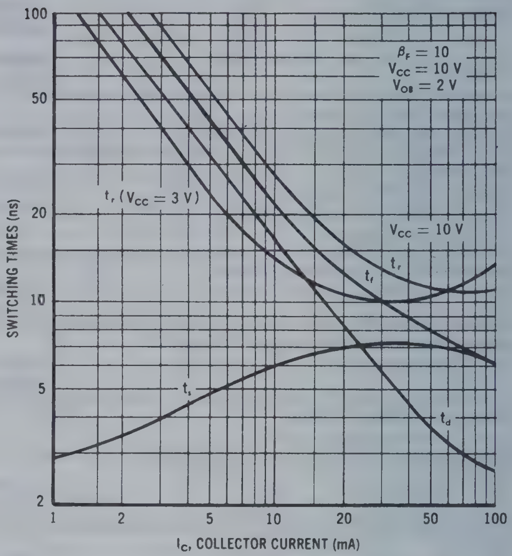


FIGURE 7 – MAXIMUM CHARGE DATA

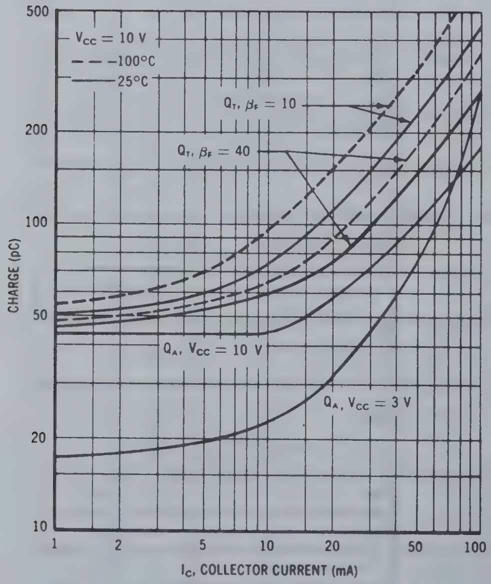


FIGURE 8 – Q_T TEST CIRCUIT

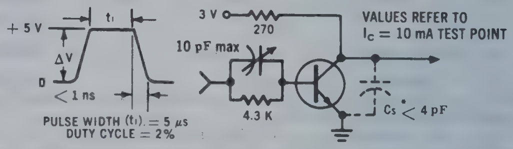

+5 V
t_1
ΔV
0
< 1 ns
PULSE WIDTH (t_1) = 5 μs
DUTY CYCLE = 2%
3 V
270
10 pF max
4.3 K
VALUES REFER TO
$I_C = 10$ mA TEST POINT
C_S * < 4 pF

FIGURE 9 – TURN-OFF WAVE FORM

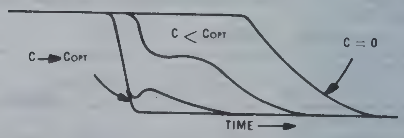
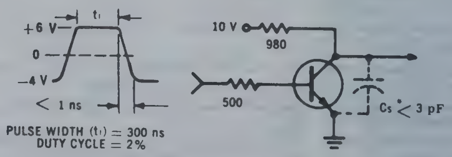


FIGURE 10 – STORAGE TIME EQUIVALENT TEST CIRCUIT


+6 V
t_1
0
−4 V
< 1 ns
PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2%
10 V
980
500
C_S * < 3 pF

* Total shunt capacitance of test jig and connectors.

FIGURE 11 — MAXIMUM COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

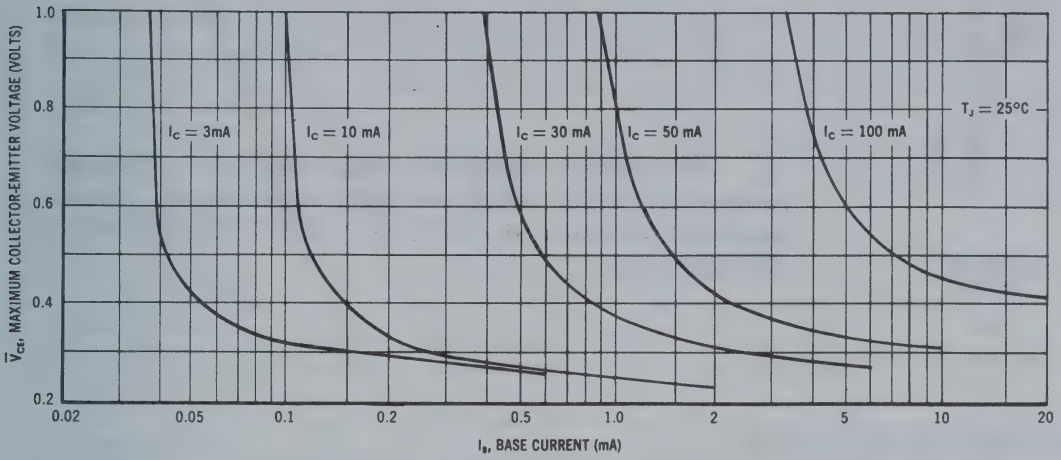


FIGURE 12 — MINIMUM CURRENT GAIN CHARACTERISTICS

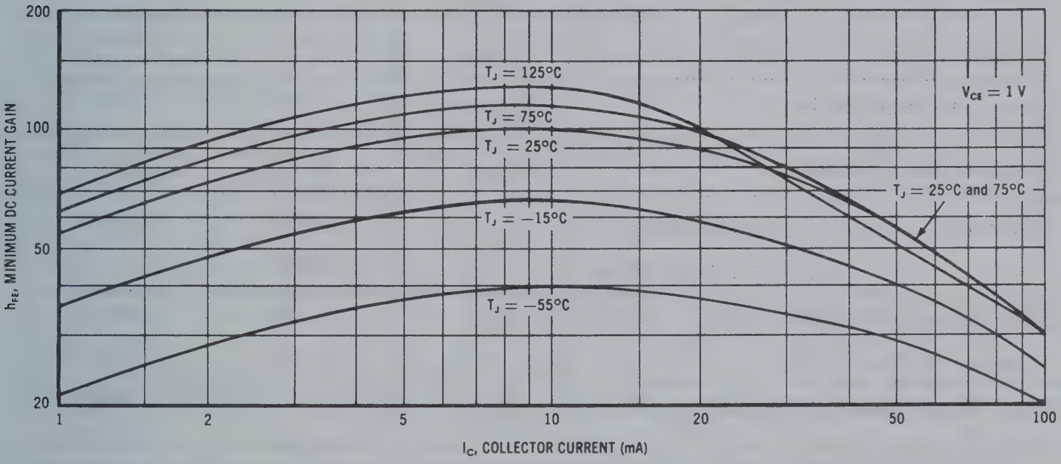


FIGURE 13 — SATURATION VOLTAGE LIMITS

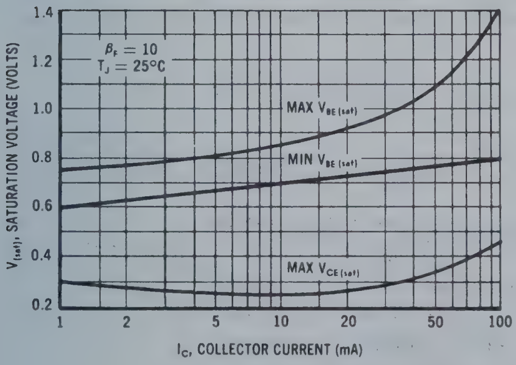
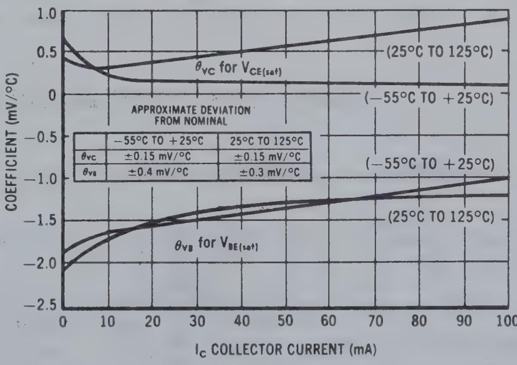
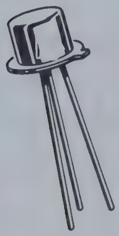


FIGURE 14 — TYPICAL TEMPERATURE COEFFICIENTS



2N2369A (SILICON)

2N2369A JAN, JTX AVAILABLE



CASE 22
(TO-18)

Collector connected to case

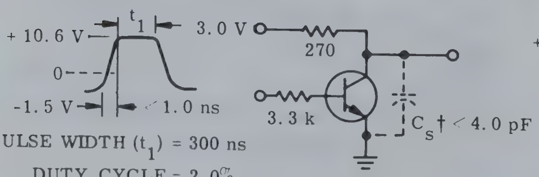
NPN silicon epitaxial transistor for high-speed range of 10 – 100 mAdc switching applications. Specifications provided at -55°C to +125°C for critical dc characteristics.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current — Continuous Peak (10 μs Pulse)	I_C	200 500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.85	Watts mW/°C
Operating Junction Temperature Range	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

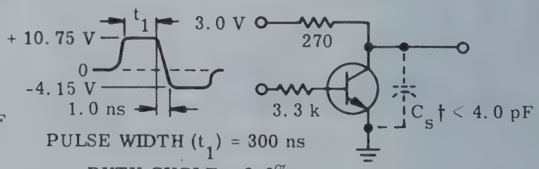
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — t_{on} CIRCUIT — 10 mA



PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2.0%

FIGURE 2 — t_{off} CIRCUIT — 10 mA



PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2.0%

† Total shunt capacitance of test jig and connectors.

2N2369A (continued)

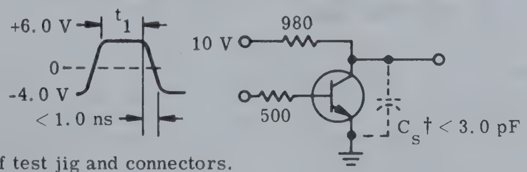
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	-	BV_{CEO}*	15	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 µAdc, I_B = 0)	-	BV_{CES}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	-	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	-	BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	-	I_{CES}	-	0.4	µAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	-	I_{CBO}	-	30	µAdc
Base Current (V_{CE} = 20 Vdc, V_{BE} = 0)	-	I_B	-	0.4	µAdc
ON CHARACTERISTICS					
DC Current Gain*	-	h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)			-	120	
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc)			40	-	
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C)			20	-	
(I_C = 30 mAdc, V_{CE} = 0.4 Vdc)			30	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)			20	-	
Collector-Emitter Saturation Voltage*	-	$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			-	0.20	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +125°C)			-	0.30	
(I_C = 30 mAdc, I_B = 3.0 mAdc)			-	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)			-	0.50	
Base-Emitter Saturation Voltage*	-	$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			0.70	0.85	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +125°C)			0.59	-	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C)			-	1.02	
(I_C = 30 mAdc, I_B = 3.0 mAdc)			-	1.15	
(I_C = 100 mAdc, I_B = 10 mAdc)			-	1.60	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	-	f_T	500	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	-	C_{ob}	-	4.0	pF
Turn-On Time (V_{CC} = 3.0 V, $V_{BE(off)}$ = 1.5 V, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc)	1	t_{on}	-	12	ns
Turn-Off Time (V_{CC} = 3.0 V, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc)	2	t_{off}	-	18	ns
Storage Time (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	3	t_s	-	13	ns

* Pulse Test: PW = 300 µs, Duty Cycle = 2.0%

FIGURE 3 — STORAGE TIME EQUIVALENT TEST CIRCUIT

PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2.0%



† Total shunt capacitance of test jig and connectors.

2N2381 (GERMANIUM)
2N2382

PNP germanium epitaxial mesa transistors for high-speed, high-current switching applications.

CASE 31
(TO-5)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N2381	2N2382	Unit
Collector-Emitter Voltage	V_{CEO}	15	20	Vdc
Collector-Base Voltage	V_{CB}	30	45	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	Vdc
Collector Current-Continuous	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25^\circ C$ Derate above $25^\circ C$	P_D	300 4.0		mW mW/°C
Total Device Dissipation @ $T_C = 25^\circ C$ Derate above $25^\circ C$	P_D	750 10		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

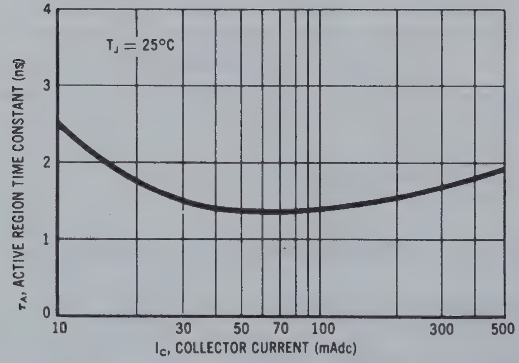


FIGURE 1 — ACTIVE REGION TIME CONSTANT

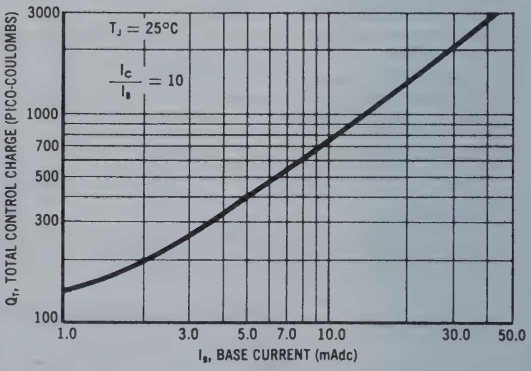


FIGURE 2 — TOTAL CONTROL CHARGE

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit

OFF CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_E = 0) 2N2381		BV_{CEO}	15	-	-	Vdc
2N2382			20	-	-	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) 2N2381		BV_{CBO}	30	-	-	Vdc
2N2382			45	-	-	
Latch-Up Voltage 2N2381	7	LV_{CEX}	20	-	-	Vdc
2N2382			25	-	-	
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) 2N2381		I_{CES}	-	-	100	μAdc
(V_{CE} = 45 Vdc, V_{BE} = 0) 2N2382			-	-	100	
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)		I_{CBO}	-	1.0	7.0	μAdc
(V_{CB} = 5 Vdc, I_E = 0, T_A = 85°C)			-	-	100	
(V_{CB} = 20 Vdc, I_E = 0) 2N2381			-	-	25	
2N2382			-	-	15	
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)		I_{EBO}	-	-	0.005	mAdc
(V_{BE} = 4 Vdc, I_C = 0)			-	-	1.0	

ON CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
DC Current Gain (I_C = 200 mAdc, V_{CE} = 0.5 Vdc)	11	h_{FE}	40	-	-	-
(I_C = 400 mAdc, V_{CE} = 1.0 Vdc)			25	-	-	
Collector-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 20 mAdc)	8, 10	$V_{CE(sat)}$	-	0.25	0.4	Vdc
(I_C = 400 mAdc, I_B = 40 mAdc)			-	0.4	0.7	
Base-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 20 mAdc)	9, 10	$V_{BE(sat)}$	0.45	0.54	0.7	Vdc
(I_C = 400 mAdc, I_B = 40 mAdc)			-	0.71	0.9	

DYNAMIC CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	300	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 4 MHz)	13	C_{ob}	-	3.5	6.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 4 MHz)	13	C_{ib}	-	8.0	15	pF
Delay Time	4	t_d	-	4.5	7.0	ns
Rise Time	4	t_r	-	8.0	15	ns
Storage Time	3, 4	t_s	-	20	30	ns
Fall Time	4	t_f	-	8.0	15	ns
Active Region Time Constant	1, 4	τ_A	-	1.6	3.0	ns

FIGURE 3 — STORAGE TIME VARIATIONS

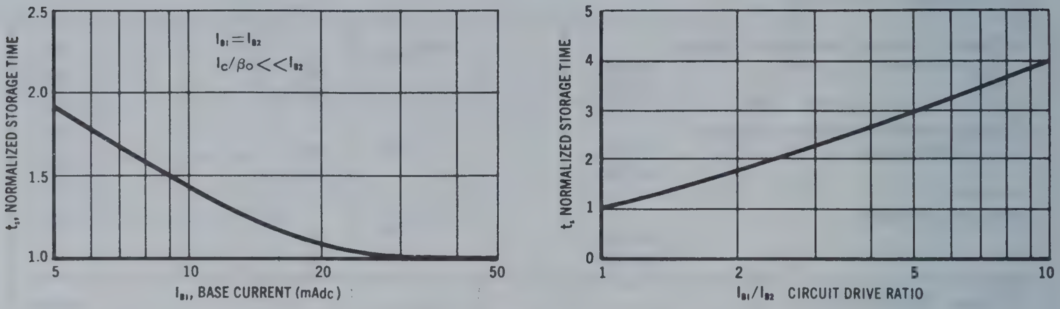


FIGURE 4 — SWITCHING TIME EQUATIONS & TEST CIRCUIT

Rise Time $= t_r = \tau_A \beta_F R$ = 10 to 90% Rise Time (fig. 5)
Fall Time $= t_f = \tau_A \beta_C F$ = 10 to 90% Fall Time (fig. 6)
$\beta_O = h_{FE}$ at Edge of Saturation
$\beta_C = I_C$ in Saturation / I_{B2} (Base "OFF" Current)
$\beta_F = I_C$ in Saturation / I_{B1} (Base "ON" Current)

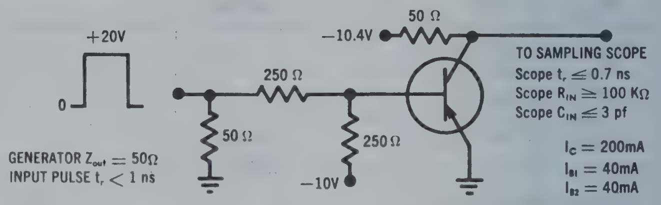

+20V
0
GENERATOR $Z_{out} = 50\Omega$
INPUT PULSE $t_r < 1$ ns
50 Ω
−10.4V
250 Ω
50 Ω
250 Ω
−10V
TO SAMPLING SCOPE
Scope $t_r \leq 0.7$ ns
Scope $R_{IN} \geq 100$ KΩ
Scope $C_{IN} \leq 3$ pf
$I_C = 200$mA
$I_{B1} = 40$mA
$I_{B2} = 40$mA

FIGURE 5 — RISE TIME FACTOR

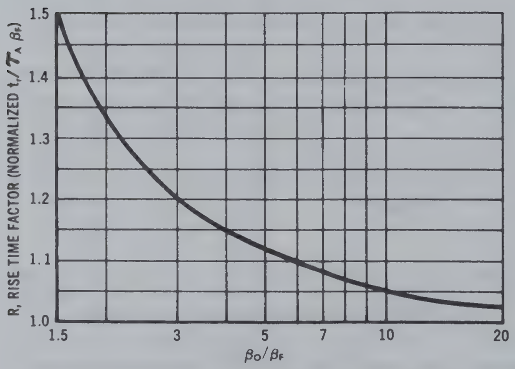


FIGURE 6 — FALL TIME FACTOR

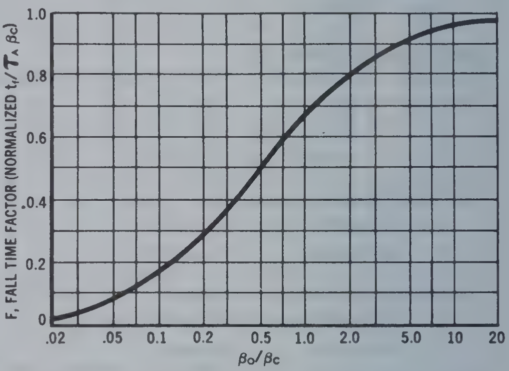


FIGURE 7 — COLLECTOR LATCH-UP VOLTAGE AND TEST CIRCUIT

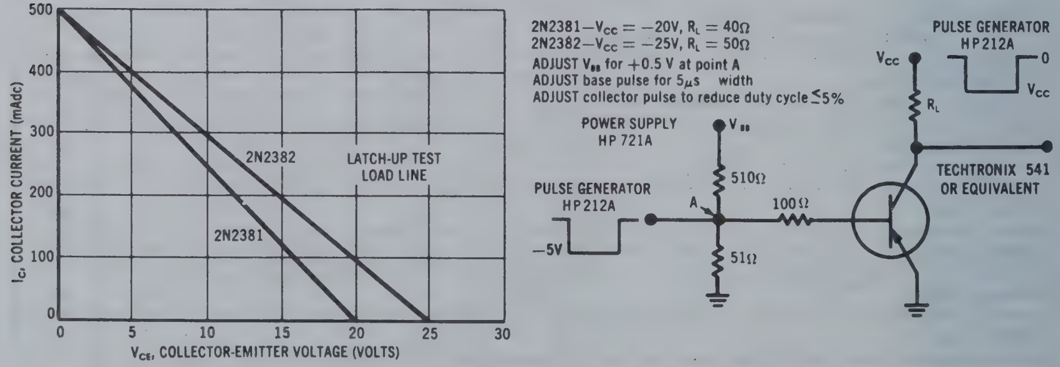

2N2381—$V_{CC} = -20$V, $R_L = 40\Omega$
2N2382—$V_{CC} = -25$V, $R_L = 50\Omega$
ADJUST V_{BB} for +0.5 V at point A
ADJUST base pulse for 5μs width
ADJUST collector pulse to reduce duty cycle ≤5%

FIGURE 8 — COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

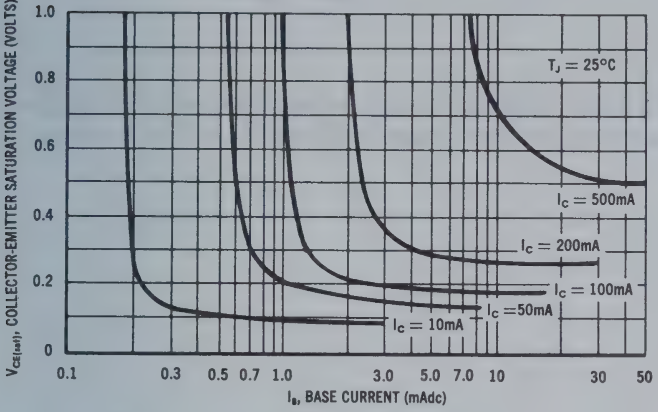


FIGURE 9 — BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

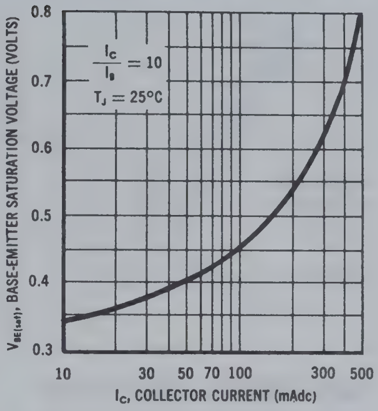


FIGURE 10 — TEMPERATURE COEFFICIENTS

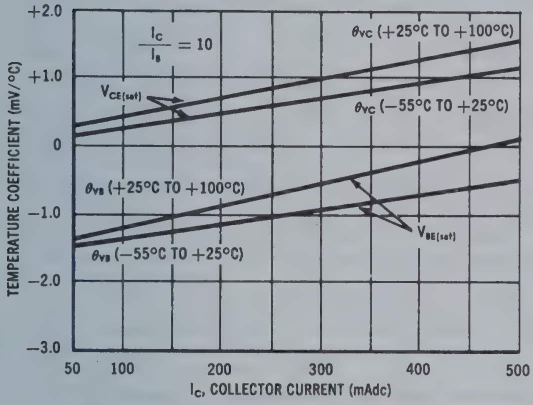


FIGURE 11 — NORMALIZED GAIN CHARACTERISTICS

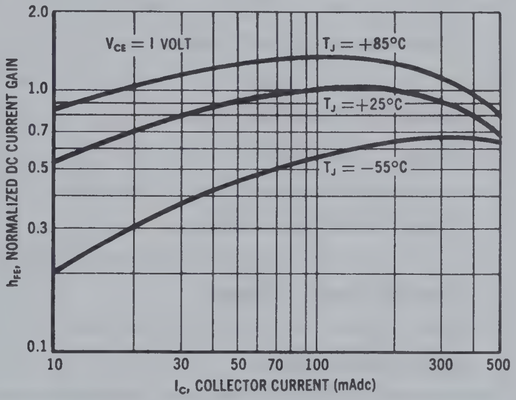
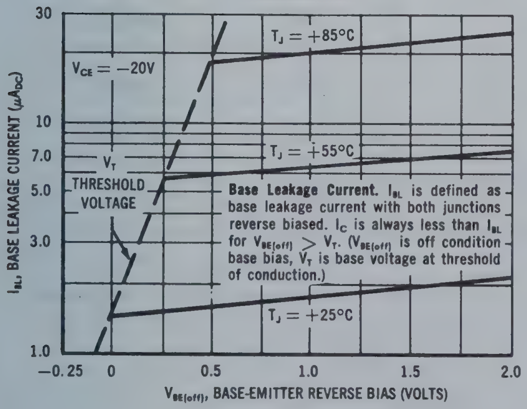
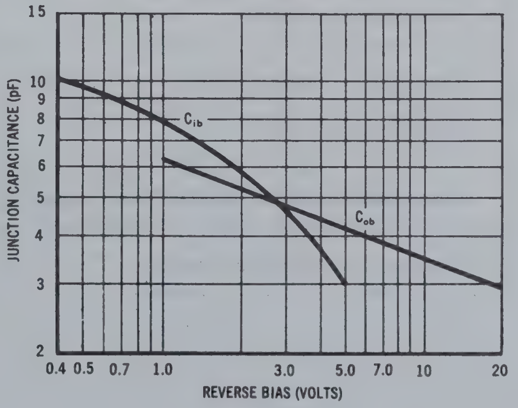


FIGURE 12 — LEAKAGE CHARACTERISTICS COMMON EMITTER



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{BE(off)} > V_T$. ($V_{BE(off)}$ is off condition base bias, V_T is base voltage at threshold of conduction.)

FIGURE 13 — JUNCTION CAPACITANCE versus REVERSE VOLTAGE



2N2405

For Specifications, See 2N1893 Data.

2N2410 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Emitter Voltage R_{BE} = 10 ohms	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	800	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	800 4.57	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.5 14.3	Watts mW/°C
Operating Junction Temperature Range	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

2N2410 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 30 mAdc, I_B = 0)	BV_{CEO} (sus)	30	—	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 30 mAdc, R_{BE} = 10 ohms)	BV_{CER}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) (V_{CE} = 30 Vdc, V_{BE} = 0, T_A = 150°C)	I_{CES}	— —	0.3 350	µAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	—	0.3	µAdc
Emitter Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)	I_{EBO}	—	0.3	µVdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 1 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc) (I_C = 500 mAdc, V_{CE} = 10 Vdc)	h_{FE}	30 15 30 25	120 — 120 100	—
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$	— —	0.45 1.3	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$	— —	1.2 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	11	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)	C_{ib}	—	50	pF
Turn-On Time (t_d + t_r) (I_C = 150 mAdc, Figure 1) (I_C = 500 mAdc, Figure 2)	t_{on}	— —	65 65	ns
Turn-Off Time (t_s + t_f) (I_C = 150 mAdc, Figure 1) (I_C = 500 mAdc, Figure 2)	t_{off}	— —	55 65	ns
Storage Time (I_C = 150 mAdc, Figure 1)	t_s	—	40	ns
Fall Time (I_C = 150 mAdc, Figure 1)	t_f	—	30	ns

(1) Pulse Test: Pulse Width = 300 µs; Duty Cycle = 2%

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — I_C = 150 mA

t_r ≤ 1 ns, PULSE WIDTH ≥ 300 ns

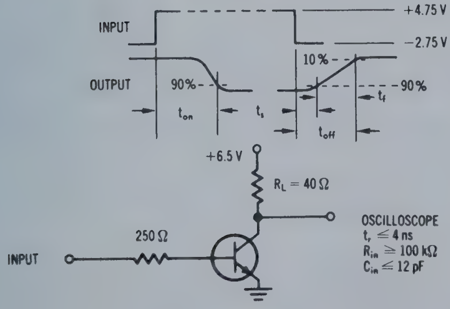
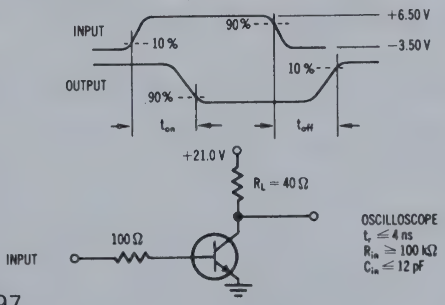

INPUT
+4.75 V
−2.75 V
OUTPUT
90%
10%
90%
t_{on}
t_s
t_f
t_{off}
+6.5 V
R_L = 40 Ω
250 Ω
INPUT
OSCILLOSCOPE
t_r ≤ 4 ns
R_{in} ≥ 100 kΩ
C_{in} ≤ 12 pF

FIGURE 2 — I_C = 500mA

t_r ≤ 12 ns, t_f ≤ 12 ns, PULSE WIDTH = 1.5 µs ± 0.5 µs, PRR ≤ 500 Hz


INPUT
+6.50 V
−3.50 V
90%
10%
OUTPUT
10%
90%
t_{on}
t_{off}
+21.0 V
R_L = 40 Ω
100 Ω
INPUT
OSCILLOSCOPE
t_r ≤ 4 ns
R_{in} ≥ 100 kΩ
C_{in} ≤ 12 pF

2N2415 (GERMANIUM)
2N2416

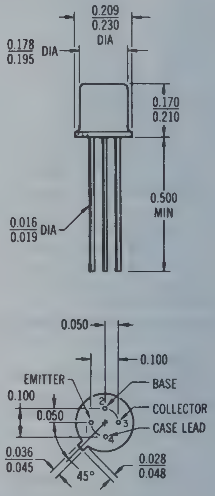
GERMANIUM ULTRA-HIGH-FREQUENCY TRANSISTORS

. . . for very low-noise, high-gain amplifiers, oscillators, mixers, and frequency multipliers.

- High Maximum Frequency of Oscillation
  $f_{max} = 2000$ MHz typ
- Low Noise Figure
  NF = 3.0 dB max at 200 MHz (2N2415)
- High Maximum Available Gain
  MAG = 14 dB typ at 500 MHz for 2N2415
  MAG = 12.5 dB typ at 500 MHz for 2N2416
- High Breakdown Voltages
  $BV_{CBO} = 25$ Volts typ
  $BV_{CEO} = 15$ Volts typ
- Low Output Capacitance
  $C_{ob} = 0.9$ pF typ

AMPLIFIER TRANSISTORS

GERMANIUM PNP
EPITAXIAL MESA
DIFFUSED BASE


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
EMITTER
BASE
0.100
0.050
COLLECTOR
CASE LEAD
1
2
3
4
0.036
0.045
45°
0.028
0.048

TO-72 PACKAGE

CASE 20

MAXIMUM RATINGS*

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	10	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Collector Current	I_C	20	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	75 1.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

* The maximum rating is that value above which device operation may be impaired from the viewpoint of life or performance.

2N2415, 2N2416 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

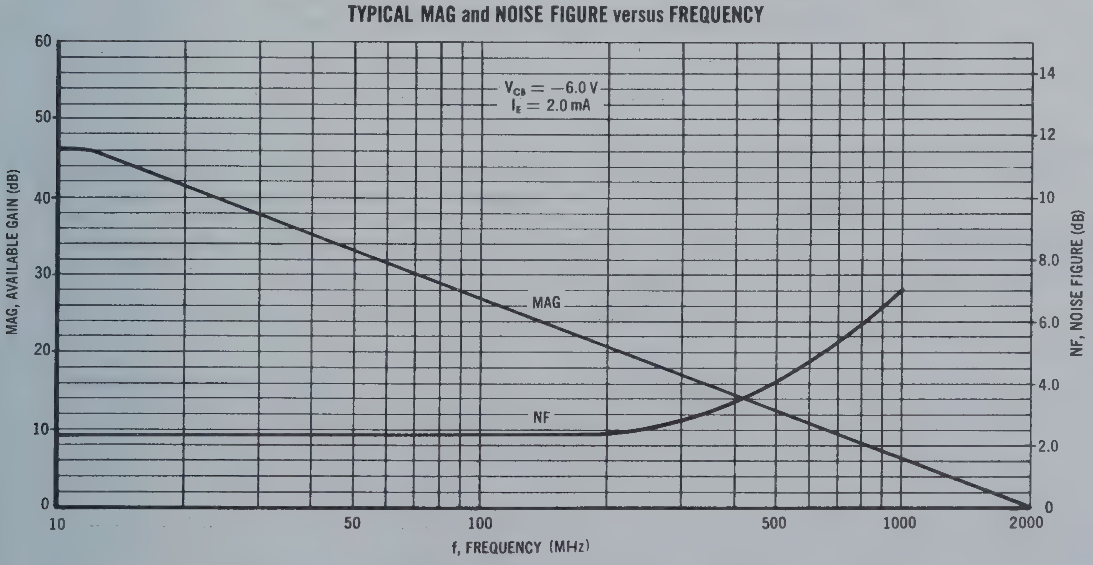
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 2.0 mAdc, I_B = 0)	BV_{CEO}	10	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	25	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	1.0	5.0	μAdc
Emitter Cutoff Current (V_{BE} = 0.3 Vdc, I_C = 0)	I_{EBO}	-	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc) 2N2415 2N2416	h_{FE}	10 8.0	- -	200 200	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc, f = 200 MHz) 2N2415 2N2416	f_T	500 400	- -	- -	MHz
Output Capacitance (V_{CB} = 6.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	0.9	2.0	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz) 2N2415 2N2416	h_{fe}	15 10	- -	300 300	-
Collector-Base Time Constant** (I_E = 2.0 mAdc, V_{CB} = 6.0 Vdc, f = 79.8 MHz) 2N2415 2N2416	$r_b'C_c$ **	- -	- -	8.0 10	ps
Noise Figure (V_{CB} = 6.0 Vdc, I_E = 1.5 mAdc, R_S = 75 ohms, f = 200 MHz) 2N2415 2N2416	NF	- -	2.4 3.4	3.0 4.0	dB
FUNCTIONAL TESTS					
Maximum Available Gain# (V_{CB} = 6.0 Vdc, I_E = 2.0 mAdc, f = 500 MHz) 2N2415 2N2416	MAG#	- -	14 12.5	- -	dB

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

** Direct Collector-Emitter header capacitance balanced out to give true device capability.

# MAG calculated from f_{max} as determined from actual amplifier circuits.

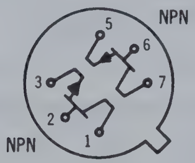
TYPICAL MAG and NOISE FIGURE versus FREQUENCY



2N2453 (SILICON)
2N2453A

Case 654-04
TO-78

Dual NPN silicon transistors designed for differential amplifier applications.



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View

All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	2N2453	2N2453A	Unit
Collector-Emitter Voltage	V_{CEO}	30	50	Vdc
Collector-Base Voltage	V_{CB}	60	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		C
		One Side	Both Sides	
Power Dissipation @ T_A = 25°C	P_D	200	300	mW
Derate above 25°C		1.14	1.71	mW/°C
Power Dissipation @ T_C = 25°C	P_D	600	1200	mW
T_C = 100°C		350	700	mW
Derate above 25°C		3.43	6.86	mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	2N2453	$BV_{CEO(sus)}$*	30	-	Vdc
	2N2453A		50	-	
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N2453	BV_{CBO}	60	-	Vdc
	2N2453A		80	-	
Emitter Base Breakdown Voltage (I_E = 0.1 μAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)		I_{CBO}	-	0.005	μAdc
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)			-	10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	0.002	μAdc

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		80	-	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)		40	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		150	600	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)		75	-	
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	5.0	-	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{re}	-	6.0	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	150	600	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	5.0	30	μmhos
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	Ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	5.0	X 10^{-4}
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.2	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz)	NF	-	7.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**			-
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2453A		0.90	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		0.90	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C)		0.85	1.0	
Base Voltage Differential	$\lvert V_{BE1}-V_{BE2}\rvert$			mVdc
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		-	3.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		-	5.0	
Base Voltage Differential Gradient (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C)	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$			μV/°C
2N2453		-	10	
2N2453A		-	5.0	

** Lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2476 (SILICON)
2N2477

CASE 31
(TO-5)

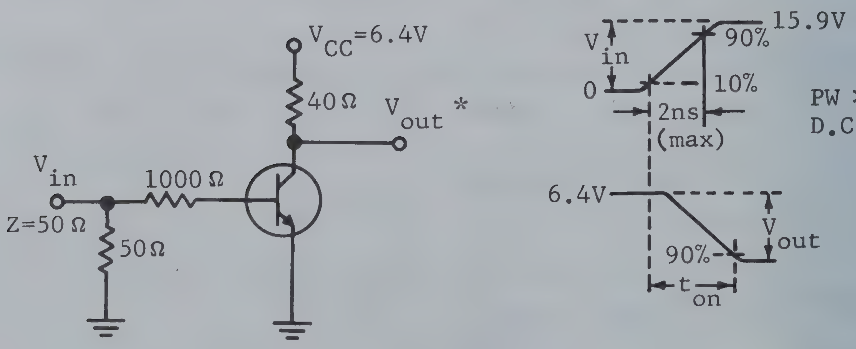
Collector connected to case

NPN silicon annular transistors designed for high-speed, low-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.4	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	2.0 11.4	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — TURN-ON TIME TEST CIRCUIT



VCC=6.4V
40 Ω
V out *
V in
1000 Ω
Z=50 Ω
50 Ω
15.9V
V in
90%
0
10%
2ns (max)
PW >150 ns
D.C. < 2%
6.4V
V out
90%
t on

*Input and output waveforms monitored by means of an oscilloscope or other indicating device having a rise time<0.5 ns; input capacitance of probe < 2.5 pF with shunt resistance ≥ 1 megohm.

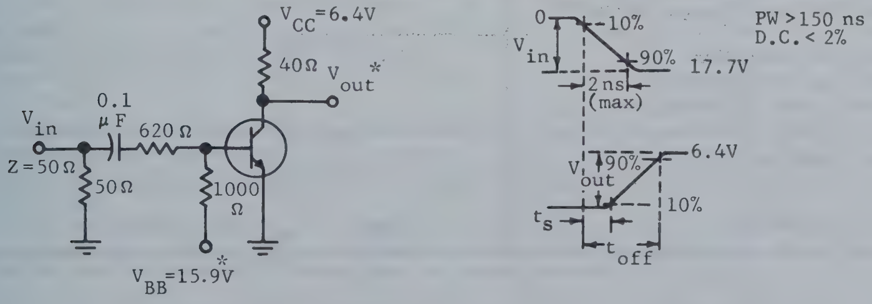
2N2476, 2N2477 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage [1] (I_C = 50 mAdc, I_B = 0)	BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.2 200	µAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	100	µAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 150 mAdc, V_{CE} = 0.4 Vdc) 2N2476 2N2477	h_{FE}	20 40	- -	-
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 7.5 mAdc) 2N2476 (I_C = 150 mAdc, I_B = 3.75 mAdc) 2N2477 (I_C = 500 mAdc, I_B = 50 mAdc) 2N2476 2N2477	$V_{CE(sat)}$	- - - -	0.4 0.4 0.75 0.65	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 7.5 mAdc) 2N2476 (I_C = 150 mAdc, I_B = 3.75 mAdc) 2N2477	$V_{BE(sat)}$	- -	1.0 0.95	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	10	pF
Turn-On Time (Figure 1) (V_{CC} = 6.4 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc)	t_{on}	-	25	ns
Turn-Off Time (Figure 2) (V_{CC} = 6.4 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)	t_{off}	-	45	ns
Storage Time (Figure 2) (I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)	t_s	-	25	ns

[1] Pulse Test: pulse width ≤ 400 µs, duty cycle ≤ 3%.

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT



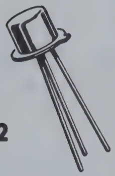
*Input and output waveforms monitored by means of an oscilloscope or other indicating device having a rise time < 0.5 ns; input capacitance of probe < 2.5 pF with shunt resistance ≥ 1 megohm.

2N2480, A

For Specifications, See 2N2060 Data.

2N2481 (SILICON)

2N2481 JAN, JTX AVAILABLE



CASE 22
(TO-18)

Collector connected to case

NPN silicon annular transistor for high-speed switching applications.

MAXIMUM RATINGS

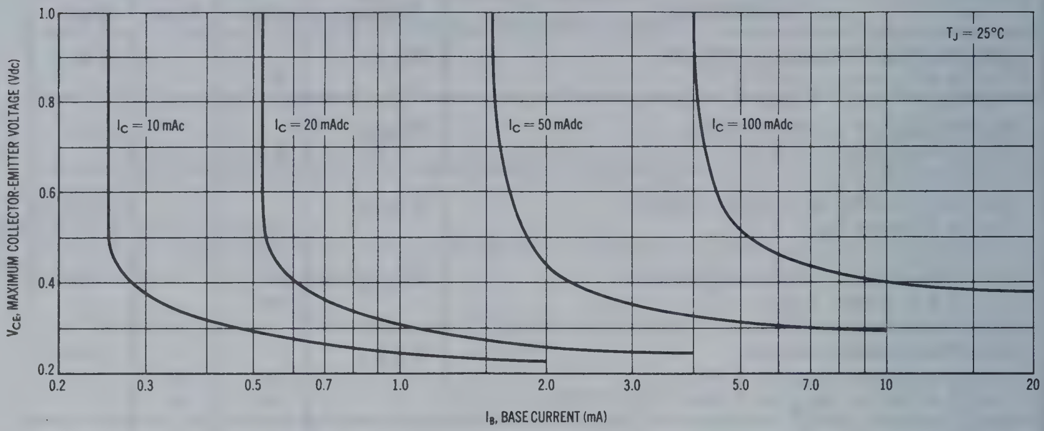
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ 25°C Ambient Temperature (Derate 2.06 mW/°C above 25°C)	P_D	0.36	Watt
Total Device Dissipation @ 25°C Case Temperature (Derate 6.9 mW/°C above 25°C)	P_D	1.2	Watts
Junction Temperature	T_J	200	°C
Storage Temperature	T_{stg}	-65 to + 200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

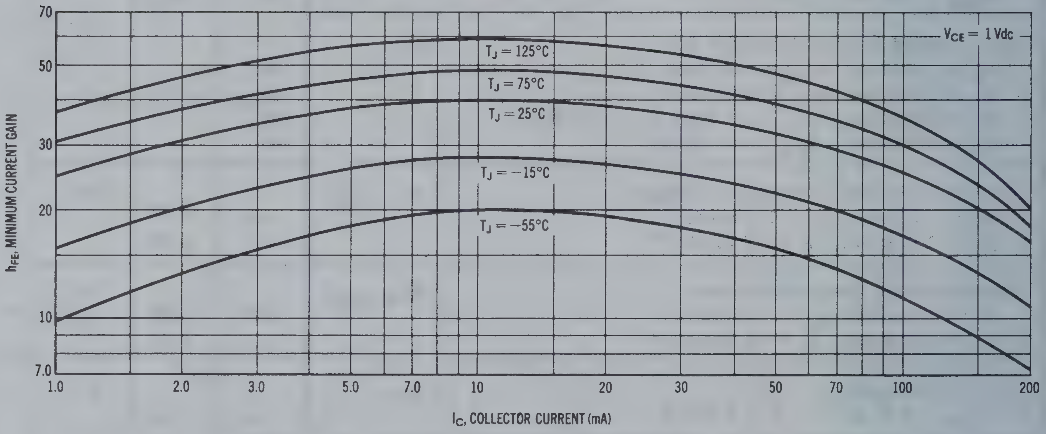
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)		40	---	
Emitter-Base Breakdown Voltage	BV_{EBO}			Vdc
(I_E = 100 μAdc, I_C = 0)		5.0	---	
Collector-Emitter Breakdown Voltage*	BV_{CEO}			Vdc
(I_C = 30 mAdc, I_B = 0)		15	---	
Collector-Emitter Breakdown Voltage	BV_{CES}			Vdc
(I_C = 1.0 μAdc, V_{BE} = 0)		30	---	
Collector Leakage Current	I_{CEX}			μAdc
(V_{CE} = 20 Vdc, V_{BE} = 3 Vdc)		---	0.050	
(V_{CE} = 20 Vdc, V_{BE} = 3 Vdc, T_A = 150°C)		---	15	
Base Leakage Current	I_{BL}			nAdc
(V_{CE} = 20 Vdc, V_{BE} = 3 Vdc)		---	50	
Emitter Cutoff Current	I_{EBO}			nAdc
(V_{EB} = 4.0 Vdc, I_C = 0)		---	100	
DC Forward Current Transfer Ratio	h_{FE}			---
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)		25	---	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)*		40	120	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (1)		20	---	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc) (1)		20	---	
Collector-Emitter Saturation Voltage	$V_{CE\,(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		---	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc) (1)		---	0.40	
Base-Emitter Saturation Voltage	$V_{BE\,(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		0.7	0.82	
(I_C = 100 mAdc, I_B = 10 mAdc) (1)		---	1.25	
Output Capacitance	C_{ob}			pF
(V_{CB} = 5 V, I_C = 0, f = 1 MHz)		---	5.0	
Input Capacitance	C_{ib}			pF
(V_{EB} = 0.5 V, f = 1 MHz)		---	7.0	
Small-Signal Forward Current Transfer Ratio	h_{fe}			---
(V_{CE} = 10 V, I_C = 10 mA, f = 100 MHz)		3.0	---	
Small-Signal, Short-Circuit, Input Impedance (Real part)	$Re(h_{ie})$			ohms
(I_C = 10 mA, V_{CE} = 10 V, f = 250 MHz)		---	60	
Turn-On Time	t_{on}			ns
(I_C = 100 mA, I_{B1} = 10 mA, $V_{BE\,(off)}$ = 2 V)		---	40	
(I_C = 10 mA, I_{B1} = 1.0 mA, $V_{BE\,(off)}$ = 2 V)		---	75	
Turn-Off Time	t_{off}			ns
(I_C = 100 mA, I_{B1} = 10 mA, I_{B2} = 5 mA)		---	55	
(I_C = 10 mA, I_{B1} = 1.0 mA, I_{B2} = 0.5 mA)		---	45	
Storage Time	t_s			ns
(I_C = 10 mA, I_{B1} = 10 mA, I_{B2} = 10 mA)		---	20	

(1) Pulse width $\leq$ 300 μs, Duty Cycle $\leq$ 2%

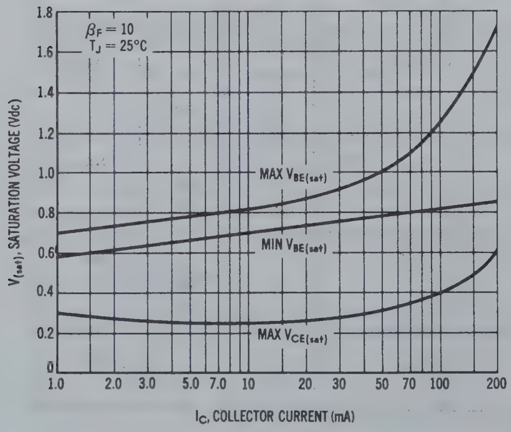
COLLECTOR SATURATION VOLTAGE CHARACTERISTICS



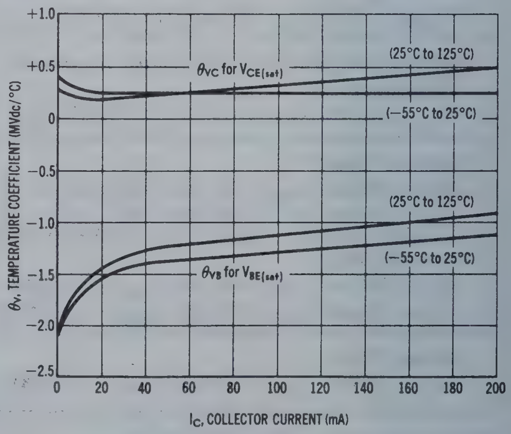
MINIMUM CURRENT GAIN CHARACTERISTICS



LIMITS OF SATURATION VOLTAGES

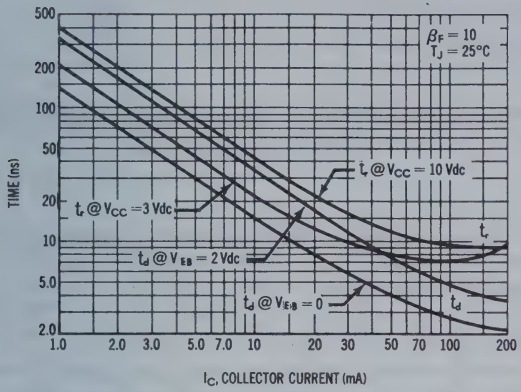


TYPICAL TEMPERATURE COEFFICIENTS

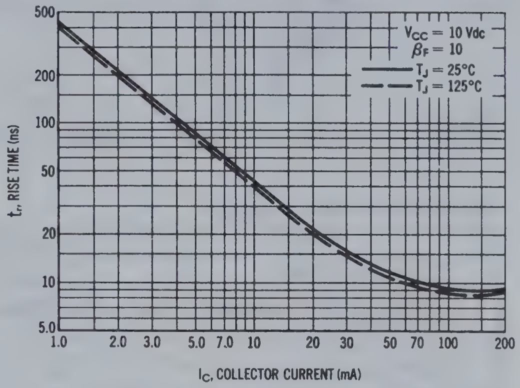


TYPICAL SWITCHING CHARACTERISTICS

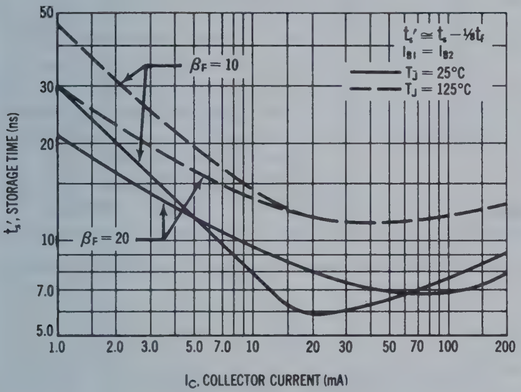
TURN-ON TIME VARIATIONS WITH VOLTAGE



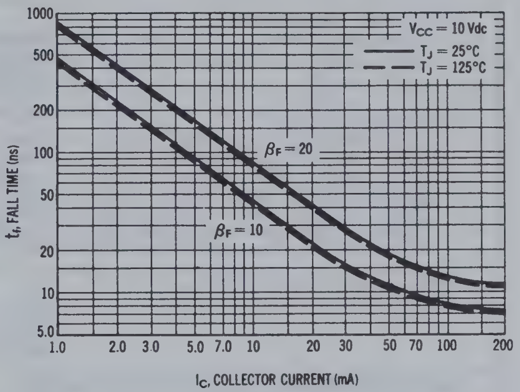
RISE TIME BEHAVIOR



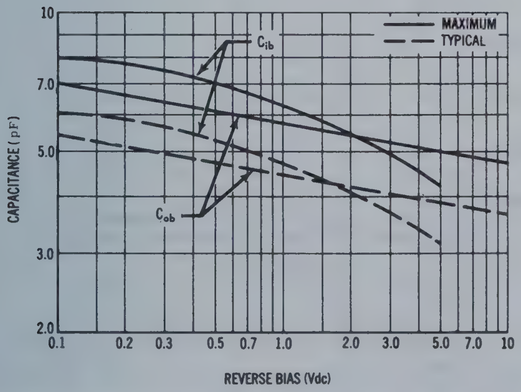
STORAGE TIME BEHAVIOR



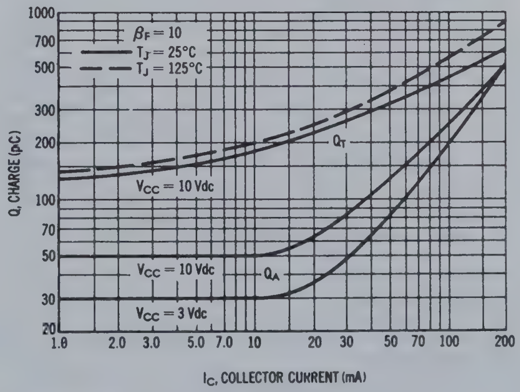
FALL TIME BEHAVIOR



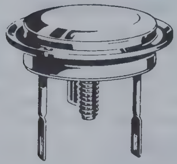
JUNCTION CAPACITANCE VARIATIONS



MAXIMUM CHARGE DATA



2N2490 thru 2N2493 (GERMANIUM)



CASE 5
(TO-36)

PNP germanium power transistors for general purpose power and switching applications.

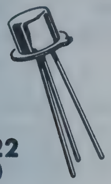
MAXIMUM RATINGS

Rating	Symbol	2N2490	2N2491	2N2492	2N2493	Unit
Collector-Base Voltage	V_{CB}	70	60	80	100	Volts
Collector-Emitter Voltage	V_{CES}	60	50	70	85	Volts
Emitter-Base Voltage	V_{EB}	40	30	60	80	Volts
Collector Current	I_C	15				Amp
Power Dissipation at $T_C = 25^oC$	P_D	170				Watts
Junction Temperature Range	T_J	-65 to +110				^oC

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current ($V_{CB} = -2$ Vdc)		I_{CBO}	—	0.2	mAdc
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = -40 Vdc)	2N2490		—	3.0	
(V_{EB} = -30 Vdc)	2N2491		—	3.0	
(V_{EB} = -60 Vdc)	2N2492		—	2.0	
(V_{EB} = -80 Vdc)	2N2493		—	3.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = -70 Vdc, V_{BE} = 1.5 Vdc)	2N2490		—	3.0	
(V_{CE} = -60 Vdc, V_{BE} = 1.5 Vdc)	2N2491		—	3.0	
(V_{CE} = -80 Vdc, V_{BE} = 1.5 Vdc)	2N2492		—	2.0	
(V_{CE} = -100 Vdc, V_{BE} = 1.5 Vdc)	2N2493		—	3.0	
(V_{CE} = -35 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^oC$)	2N2490,2N2491		—	35	
(V_{CE} = -40 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^oC$)	2N2492		—	35	
(V_{CE} = -50 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^oC$)	2N2493		—	35	
Collector-Emitter Breakdown Voltage (I_C = 1 A, I_B = 0)		V_{CEO}			Volts
	2N2490		50	—	
	2N2491		40	—	
	2N2492		65	—	
	2N2493		75	—	
Base-Emitter Voltage		V_{BE}			Vdc
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N2490,2N2491		—	0.9	
	2N2492,2N2493		—	0.8	
(I_C = 12 Adc, V_{CE} = -2 Vdc)			—	1.5	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 12 Adc, I_B = 2 Adc)	2N2490, 2N2491		—	0.7	
	2N2492, 2N2493		—	0.5	
DC Current Gain		h_{FE}			—
(I_C = 1 Adc, V_{CE} = -2 Vdc)	2N2490		45	—	
	2N2491		65	—	
	2N2492, 2N2493		50	—	
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N2490		20	40	
	2N2491		35	70	
	2N2492, 2N2493		25	50	
(I_C = 5 Adc, V_{CE} = -2 Vdc, $T_A = -65^oC$)	2N2490		15	—	
	2N2491		25	—	
	2N2492, 2N2493		20	—	
(I_C = 12 Adc, V_{CE} = -2 Vdc)	2N2490		8	—	
	2N2491		12	—	
	2N2492, 2N2493		10	—	
Common Emitter Cutoff Frequency (I_C = 5A, V_{CE} = -6 V)		$f_{\alpha e}$	5.0	—	kHz
Turn-On Time (I_C = 5 A, $I_{B1} = I_{B2}$ = 0.5 A)		t_{on}	—	25	μs
Turn-Off Time (I_C = 5 A, $I_{B1} = I_{B2}$ = 0.5 A)		t_{off}	—	15	μs

2N2501 (SILICON)



CASE 22
(TO-18)

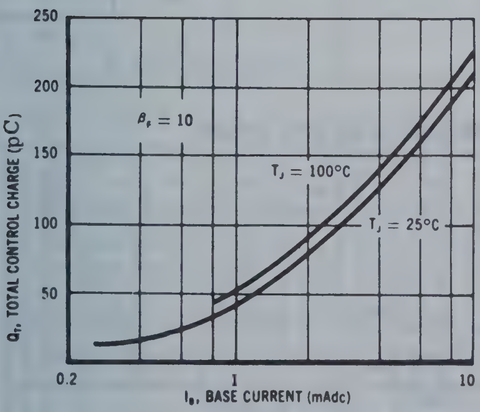
Collector connected to case

NPN silicon annular transistor for high-speed switching applications.

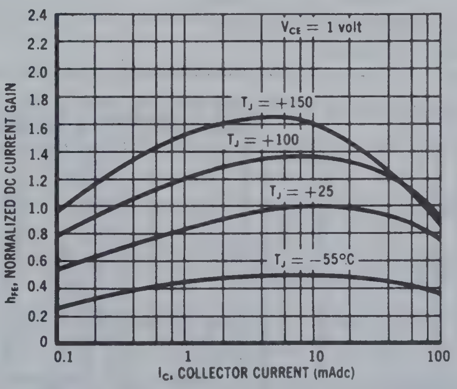
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Total Device Dissipation @ 25°C Ambient Temperature (Derate 2.06 mW/°C above 25°C)	P_D	0.36	Watts
Junction Temperature	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to + 200	°C
Total Device Dissipation @ 25°C Case Temperature (Derate 6.9 mW/°C above 25°C)	P_D	1.2	Watts

TOTAL CONTROL CHARGE



NORMALIZED CURRENT GAIN CHARACTERISTICS



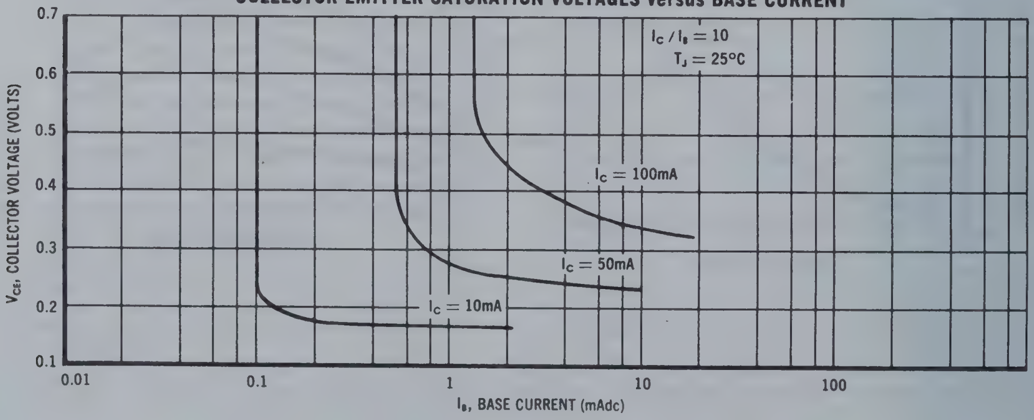
2N2501 (Continued)

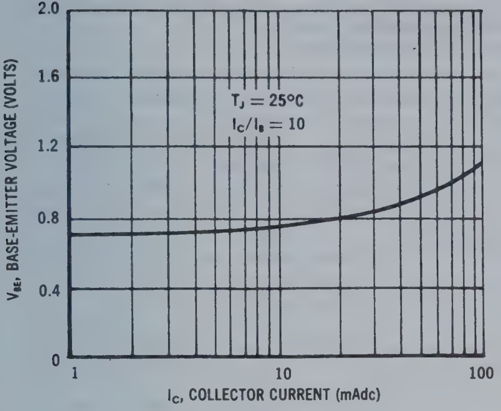
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

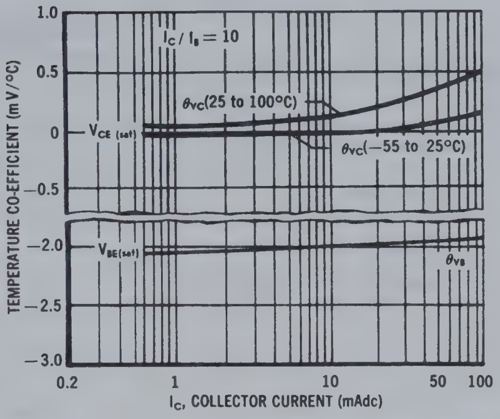
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0, Pulsed)	BV_{CEO}	20	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	–	Vdc
Collector Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc)	I_{CEX}	–	25	nAdc
Base Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc) (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc, T_A = 150°C)	I_{BL}	– –	0.025 50	μAdc μAdc
DC Forward Current Transfer Ratio* (I_C = 100 μAdc, V_{CE} = 1 Vdc) (I_C = 1 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C) (I_C = 50 mAdc, V_{CE} = 1 Vdc) (I_C = 100 mAdc, V_{CE} = 1 Vdc) (I_C = 500 mAdc, V_{CE} = 5 Vdc)	h_{FE}	20 30 50 20 40 30 10	– – 150 – – – –	–
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	– – –	0.2 0.3 0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	– – –	0.85 1.0 1.2	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	–	4.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	–	7.0	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 100 MHz)	h_{fe}	3.5	–	–
Current-Gain-Bandwidth Product (V_{CE} = 20 Vdc, I_C = 10 mAdc)	f_T	350	–	MHz
Charge Storage Time Constant (I_C = I_{B1} = I_{B2} = 10 mAdc)	τ_S	–	15	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	Q_T	–	60	pC
Active Region Time Constant (I_C = 10 mAdc)	τ_A	–	2.5	ns

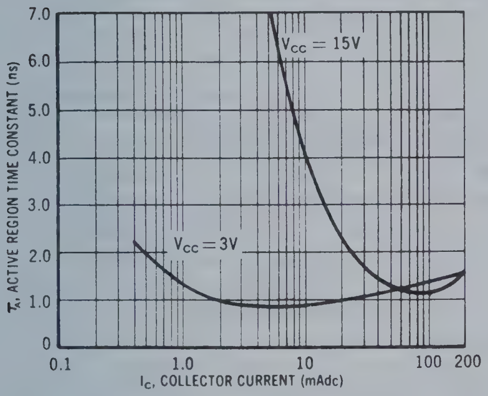
*Pulse Test: Pulse width ≦ 300 μs, duty cycle ≦ 2%

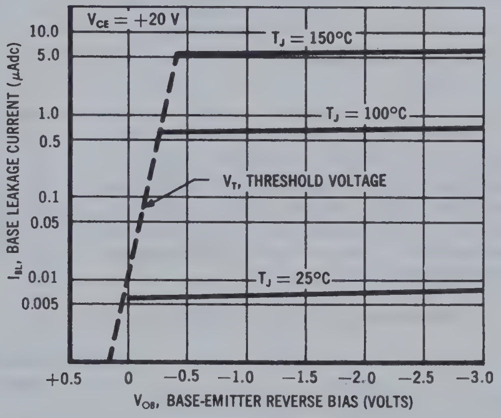
COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

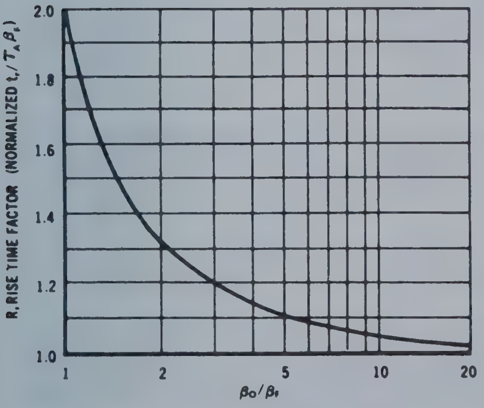


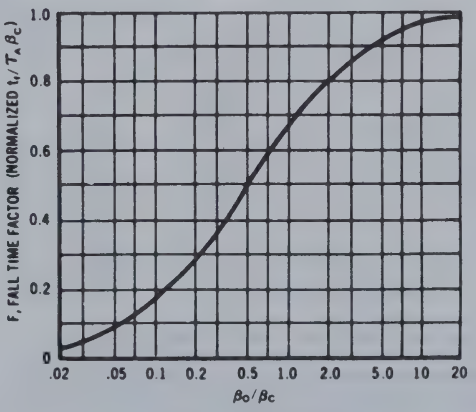

BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT


TEMPERATURE COEFFICIENTS


ACTIVE REGION TIME CONSTANT

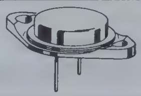

COMMON EMITTER DC LEAKAGE CHARACTERISTICS


RISE TIME FACTOR

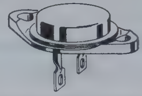

FALL TIME FACTOR

2N2526 (GERMANIUM)
2N2527
2N2528

PNIP germanium power transistors for high-voltage power switching applications.



CASE 11A
(TO-3 modified)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP2526 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N2526	2N2527	2N2528	Unit
Collector-Emitter Voltage	V_{CE}	80	120	160	Vdc
Collector-Base	V_{CB}	80	120	160	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current - Continuous	I_C	10			Adc
Base Current	I_B	5.0			Adc
Emitter Reverse Current (Surge 60 Hz Recurrent)	I_E	1.5			Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	85			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			°C

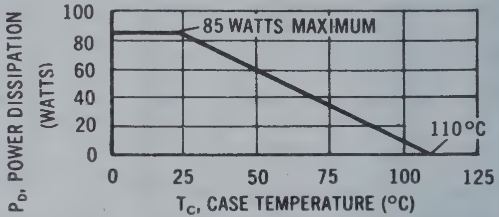
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

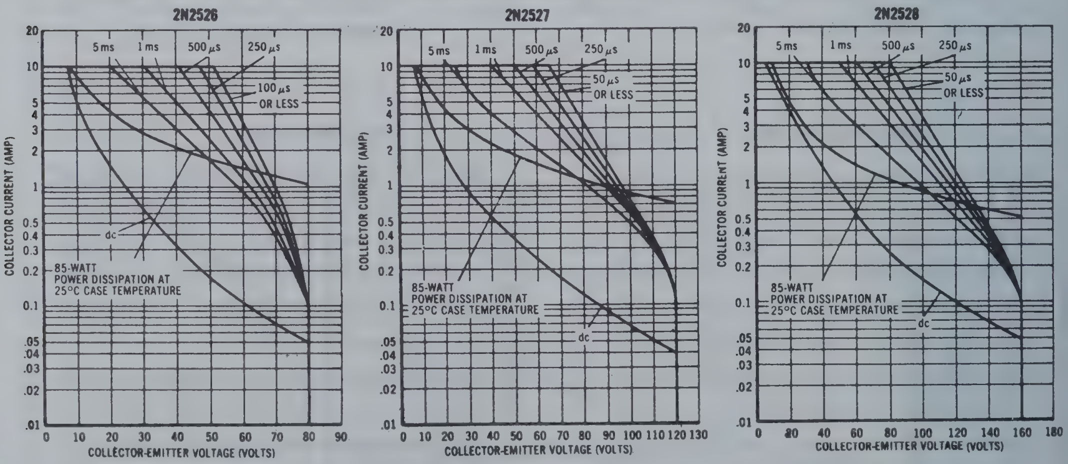
POWER-TEMPERATURE DERATING CURVE

The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 85 watts at a case temperature of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that:

$$\text{Allowable } P_D = \frac{110° - T_C}{1.0} \text{ Watts}$$



SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N2526 thru 2N2528 (continued)

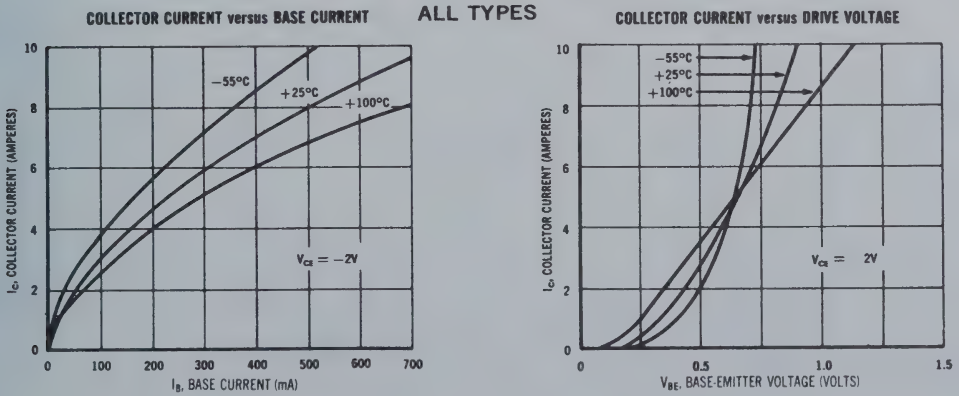
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)	2N2526	$BV_{CEO(sus)}$*	80	-	-	Volts
	2N2527		120	-	-	
	2N2528		160	-	-	
Emitter-Base Breakdown Voltage (I_E = 50 mAdc, I_C = 0)		BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current* (V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2526	I_{CEX}*	-	-	35	mAdc
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2527		-	-	35	
(V_{CE} = 160 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2528		-	-	35	
Collector-Emitter Cutoff Current (V_{CE} = 80 Vdc, R_{BE} = 100 ohms)	2N2526	I_{CER}	-	-	25	mAdc
(V_{CE} = 120 Vdc, R_{BE} = 100 ohms)	2N2527		-	-	25	
(V_{CE} = 160 Vdc, R_{BE} = 100 ohms)	2N2528		-	-	25	
Collector Cutoff Current (V_{CB} = 80 Vdc, I_E = 0)	2N2526	I_{CBO}	-	-	3.0	mAdc
(V_{CB} = 120 Vdc, I_E = 0)	2N2527		-	-	3.0	
(V_{CB} = 160 Vdc, I_E = 0)	2N2528		-	-	3.0	
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	150	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	-	50	-
DC Transconductance (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		g_{FE}	4.0	6.0	-	mhos
Collector-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)		$V_{CE(sat)}$	-	0.5	0.8	Vdc
Base-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)		$V_{BE(sat)}$	-	0.8	1.2	Vdc
DYNAMIC CHARACTERISTICS						
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 30 kHz)		h_{fe}	10	15	-	-
Rise Time		t_r	-	5.5	-	μs
Storage Time		t_s	-	1.2	-	μs
Fall Time		t_f	-	2.0	-	μs

*To avoid excessive heating of collector junction, perform this test with a sweep method.

TYPICAL INPUT CHARACTERISTICS

ALL TYPES

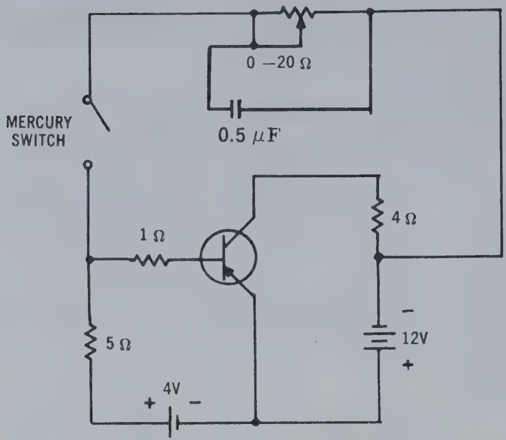


COLLECTOR CURRENT versus BASE CURRENT

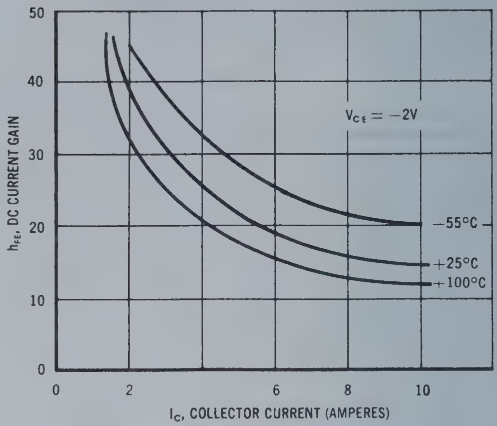
COLLECTOR CURRENT versus DRIVE VOLTAGE

SWITCHING TEST CIRCUIT

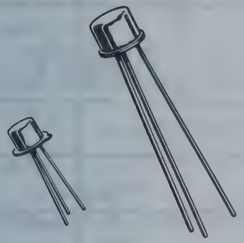
PULSE CONDITIONS ; $I_C = 3$ Adc, $I_B = 300$ mAdc


0 –20 Ω
0.5 μF
MERCURY SWITCH
1 Ω
4 Ω
5 Ω
12V
4V
+
–

DC CURRENT GAIN versus COLLECTOR CURRENT



2N2537 thru 2N2540 (SILICON)



NPN silicon annular Star transistors for high-speed switching.

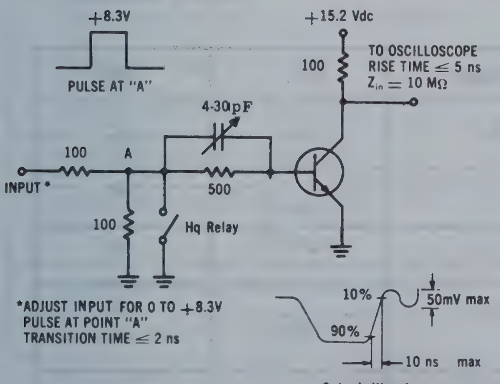
CASE 22 (TO-18)	**CASE 31** (TO-5)
2N2539 2N2540	2N2537 2N2538

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N2537 2N2538 (TO-5)	2N2539 2N2540 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	60	60	Vdc
Collector-Emitter Voltage	V_{CEO}	30	30	Vdc
Collector-Emitter Voltage	V_{CER}	40	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	3 17.2	1.8 10.3	Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	0.8 4.57	0.5 2.86	Watts mW/°C
Junction Temperature	T_J	-65 to +200		°C
Storage Temperature	T_{stg}	-65 to + 200		°C

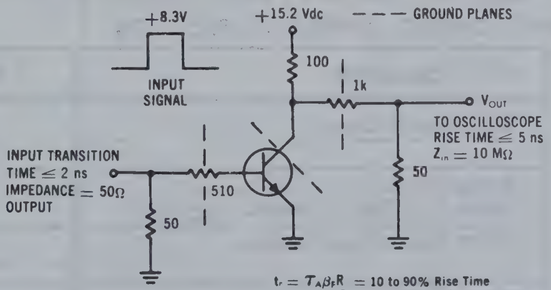
TOTAL CONTROL CHARGE TEST CIRCUIT


+8.3V
PULSE AT "A"
+15.2 Vdc
100
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Z_in = 10 MΩ
4-30 pF
100
A
INPUT *
500
100
Hq Relay
10%
50mV max
90%
10 ns max

*ADJUST INPUT FOR 0 TO +8.3V
PULSE AT POINT "A"
TRANSITION TIME ≤ 2 ns

Output Waveform

ACTIVE REGION TIME CONSTANT TEST CIRCUIT


+8.3V
INPUT SIGNAL
+15.2 Vdc
— — — GROUND PLANES
100
1k
V_OUT
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Z_in = 10 MΩ
50
INPUT TRANSITION
TIME ≤ 2 ns
IMPEDANCE = 50Ω
OUTPUT
510
50

$T_A = T_{RE} = T_{FE}$

$T_{RE} = \frac{I_{B1}}{I_{CS}} t_r$

$t_r = T_A \beta_F R$ = 10 to 90% Rise Time

$t_f = T_A \beta_C F$ = 10 to 90% Fall Time

$R = \frac{\beta_O}{\beta_F} \ln\left(\frac{\beta_O}{\beta_O - 0.9\beta_F}\right)$

$F = \frac{\beta_O}{\beta_C} \ln\left(1 + \frac{\beta_O}{\beta_C}\right)$

$\beta_O = h_{FE}$ at Edge of Saturation

$\beta_C = I_C$ in Saturation / I_{B2} (Base "OFF" Current)

$\beta_F = I_C$ in Saturation / I_{B1} (Base "ON" Current)

2N2537 thru 2N2540 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 40 Vdc, I_E = 0)		—	0.250	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 150°C)		—	200	
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	0.05	μAdc
Collector Cutoff Current (V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc)	I_{CEX}	—	0.250	μAdc
Base Cutoff Current	I_{BL}			μAdc
(V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc)		—	0.250	
(V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc, T_A = 150°C)		—	200	
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed, I_B = 0)	BV_{CEO}	30	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed, $R_{BE} \leqq 10\ \Omega$)	BV_{CER}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Saturation Voltage *	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		—	0.45	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	1.6	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc) (1)		—	1.3	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	2.6	
DC Forward Current Transfer Ratio	h_{FE}			—
(I_C = 1 mAdc, V_{CE} = 10 Vdc) 2N2537, 2N2539		20	—	
2N2538, 2N2540		35	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N2537, 2N2539		30	—	
2N2538, 2N2540		50	—	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) (1) 2N2537, 2N2539		50	150	
2N2538, 2N2540		100	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) (1) 2N2537, 2N2539		20	—	
2N2538, 2N2540		30	—	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	8.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	25	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 20 Vdc, I_C = 20 mAdc, f = 100 MHz)	h_{fe}	2.5	—	—

(1) Pulse Test: Pulse width ≦ 300 μs, duty cycle ≦ 2%

SWITCHING CHARACTERISTICS

Characteristic	Symbol	Max.	Unit
Total Control Charge	Q_T	750	pC
Storage Time ($I_C = I_{B1} = I_{B2}$ = 20 mAdc, V_{CC} = 5 V)	τ_S	20	ns
Active Region Time Constant	τ_A	2.0	ns
Turn-on Time ($I_{B1} = I_{B2}$ = 15 mAdc, I_C = 150 mAdc, V_{CC} = 7 Vdc, R_L = 40 Ω)	t_{on}	40	ns
Turn-off Time ($I_{B1} = I_{B2}$ = 15 mAdc, I_C = 150 mAdc, V_{CC} = 7 Vdc, R_L = 40 Ω)	t_{off}	40	ns

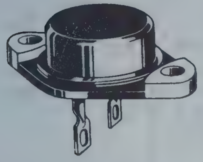
2N2552 thru 2N2559

For Specifications, See 2N1038 Data.

2N2560 thru 2N2567

For Specifications, See 2N1042 Data.

2N2573 thru 2N2579 (SILICON)



CASE 61 (TO-41) **CASE 54** (TO-3 Modified)

Industrial-type, silicon controlled rectifiers in a "diamond" package for applications requiring a high surge-current rating or low thermal resistance.

For units with pins (TO-3 Modified) specify devices MCR649AP-1(2N2573) thru MCR649AP-7(2N2579).

MAXIMUM RATINGS ($T_J = 125°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{RSM(rep)}$*		Volts
2N2573		25	
2N2574		50	
2N2575		100	
2N2576		200	
2N2577		300	
2N2578		400	
2N2579		500	
Forward Current RMS (all conduction angles)	$I_{T(RMS)}$	25	Amp
Circuit Fusing Considerations (T_J = -65° to +125°C, t ≦ 8.3 ms)	I^2t	275	A^2s
Peak Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)	I_{TSM}	260	Amp
Peak Gate Power - Forward	P_{GM}	5.0	Watts
Average Gate Power - Forward	$P_{G(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{GM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*V_{RSM} for all types can be applied on a continuous dc basis without incurring damage.

V_{RSM} Ratings apply for zero or negative gate voltage.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

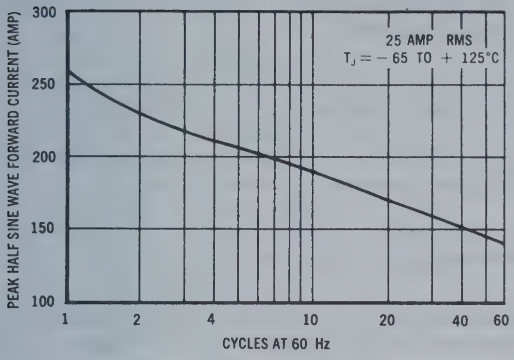
Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 125°C) 2N2573	V_{DRM}*	25	—	—	Volts
2N2574		50	—	—	
2N2575		100	—	—	
2N2576		200	—	—	
2N2577		300	—	—	
2N2578		400	—	—	
2N2579		500	—	—	
Peak Forward Blocking Current (Rated V_{DRM} with gate open, T_J = 125°C)	I_{DRM}	—	0.6	5.0	mA
Peak Reverse Blocking Current (Rated V_{RSM}, T_J = 125°C)	I_{RRM}	—	0.6	5.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 Ω)	I_{GT}	—	20	40	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 Ω)	V_{GT}	—	1.0	3.5	Volts
(V_{DRM} = Rated,R_L = 100Ω, T_J = 125°C)	V_{GNT}	0.3	—	3.5	
Forward On Voltage (I_T = 20 Adc)	V_T	—	1.1	1.4	Volts
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_H	—	20	—	mA
Turn-On Time (t_d + t_r) (I_{GT}= 50 mA, I_T = 10A)	t_{gt}	—	1.0	—	μs
Turn-Off Time (I_T = 10 A, I_R = 10 A, dv/dt = 20 V/μs, T_J = 125°C) (V_{DRM} = rated voltage)	t_q	—	30	—	μs
Forward Voltage Application Rate (Gate Open, T_J = 125°C)	dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	1.5	°C/W

*V_{DRM} for all types can be applied on a continuous dc basis without incurring damage.

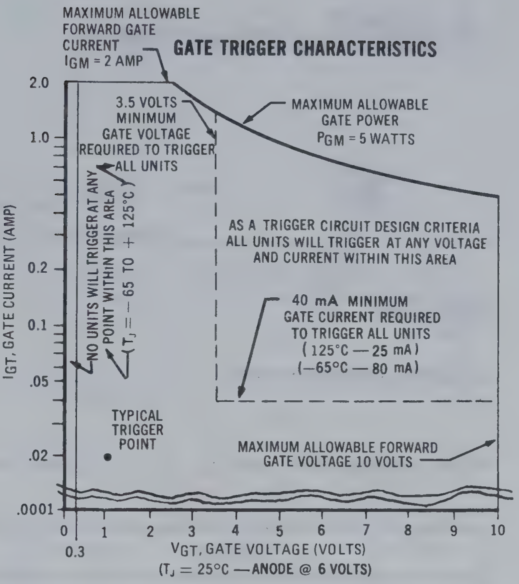
V_{DRM} ratings apply for zero or negative gate voltage.

2N2573 thru 2N2579 (continued)

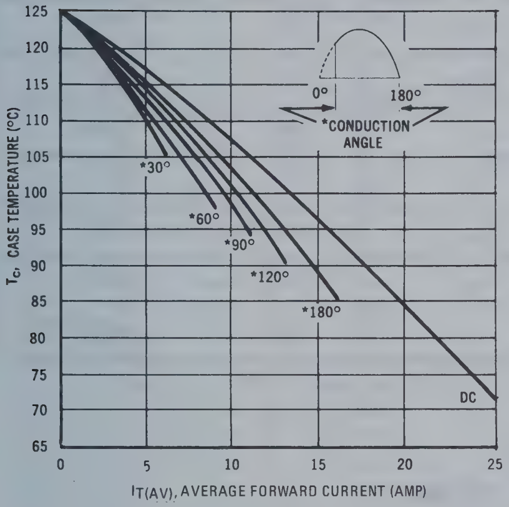
MAXIMUM ALLOWABLE NON-RECURRENT SURGE CURRENT



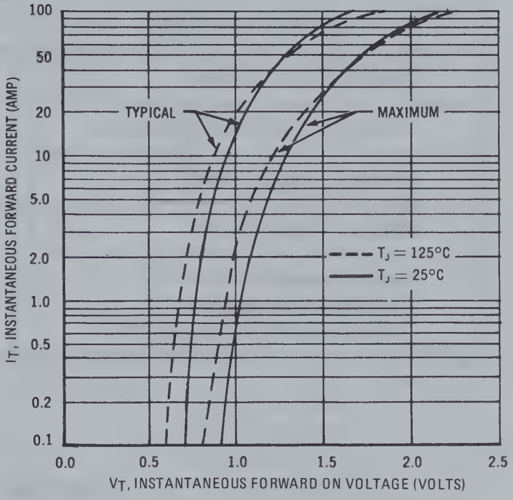
GATE TRIGGER CHARACTERISTICS



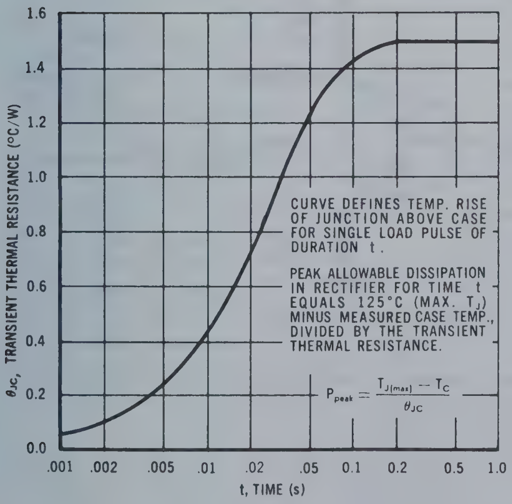
MAXIMUM ALLOWABLE CASE TEMPERATURE



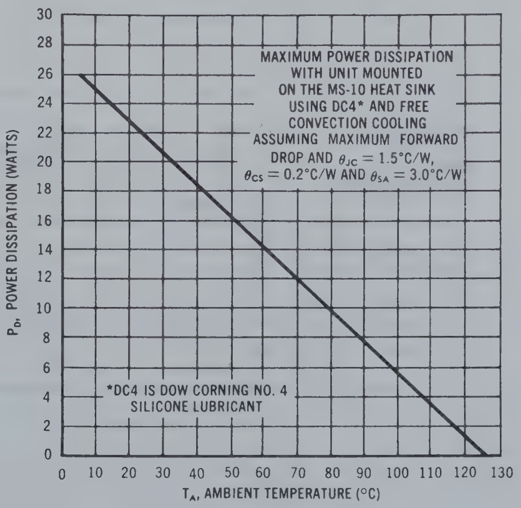
LOW CURRENT LEVEL



MAXIMUM TRANSIENT THERMAL RESISTANCE JUNCTION TO CASE



POWER DERATING CURVE



2N2635 (GERMANIUM)

CASE 22
(TO-18)

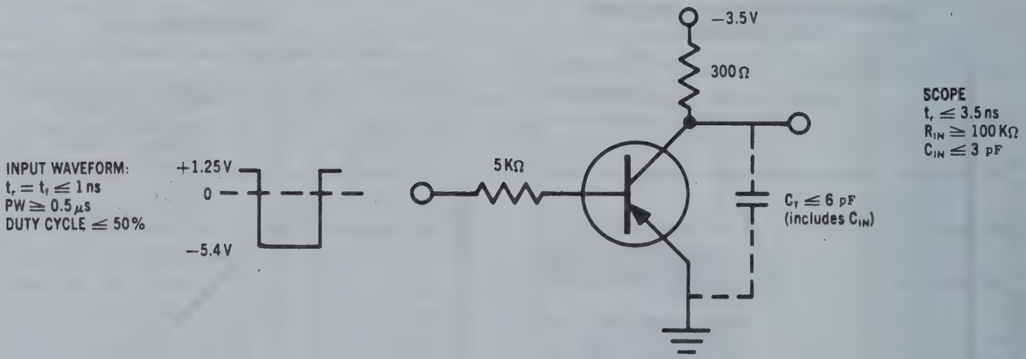
Collector connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS ($T_A = 25^{\circ}C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to + 100	°C
Device Dissipation @ 25°C Ambient Temperature (Derate 2mW/°C above 25°C)	P_D	150 2.0	mW mW/°C

SWITCHING TIME TEST CIRCUIT


−3.5 V
300 Ω
SCOPE
$t_r \leq 3.5$ ns
$R_{IN} \geq 100$ KΩ
$C_{IN} \leq 3$ pF
INPUT WAVEFORM:
$t_r = t_f \leq 1$ ns
PW ≥ 0.5 μs
DUTY CYCLE ≤ 50%
+1.25 V
0
−5.4 V
5 KΩ
$C_T \leq 6$ pF
(includes C_{IN})

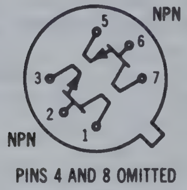
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	50	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 2 mAdc, I_B = 0)	BV_{CEO}	15	30	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.5	4.5	---	Vdc
Collector-Base Cutoff Current (V_{CB} = 25V, I_E = 0) (V_{CB} = 25V, I_E = 0, T_A = +55°C)	I_{CBO}	--- ---	1.0 5.0	5.0 20	μAdc
Emitter-Base Cutoff Current (V_{EB} = 1V, I_C = 0)	I_{EBO}	---	2.0	20	μAdc
Static Forward Current Transfer Ratio (I_C = 10 mA, V_{CE} = 0.5V) (I_C = 50 mA, V_{CE} = 1V) (I_C = 50 mA, V_{CE} = 1V, T_A = -55°C) (I_C = 100 mA, V_{CE} = 1V)	h_{FE}	30 45 25 30	--- --- --- ---	--- 300 --- ---	---
Base-Emitter Voltage (I_C = 10 mA, I_B = 0.5 mA) (I_C = 50 mA, I_B = 2.5 mA) (I_C = 50 mA, I_B = 2.5 mA, T_A = -55°C) (I_C = 100 mA, I_B = 10 mA)	V_{BE}	--- --- --- ---	0.36 0.47 0.56 0.57	0.45 0.70 0.85 0.90	Vdc
Collector-Emitter Saturation Voltage (I_C = 10 mA, I_B = 0.5 mA) (I_C = 50 mA, I_B = 2.5 mA) (I_C = 50 mA, I_B = 2.5 mA, T_A = +55°C) (I_C = 100 mA, I_B = 10 mA)	$V_{CE(sat)}$	--- --- --- ---	0.13 0.20 0.22 0.23	0.20 0.40 0.45 0.75	Vdc
Small-Signal Forward Current Transfer Ratio (I_C = 30 mA, V_{CE} = 2V, f = 100 MHz)	$\|h_{fe}\|$	1.5	---	---	---
Collector Output Capacitance (V_{CB} = 5 V, I_E = 0, f = 1 MHz)	C_{ob}	---	2.5	5.0	pF
Input Capacitance (V_{BE} = 1V, I_C = 0, f = 1 MHz)	C_{ib}	---	---	4.0	pF
Delay Time	t_d	---	15	20	ns
Rise Time	t_r	---	20	30	ns
Storage Time	t_s	---	100	185	ns
Fall Time	t_f	---	35	65	ns

2N2639 thru 2N2644 (SILICON)

Dual NPN silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N3806 series or 2N2802 series, for TO-89 flat packages see 2N3043-2N3048 series.

Case 654-04
TO-78



Pin Connections, Bottom View

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.72	600 3.43	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	600 3.43	1200 6.87	mW mW/°C

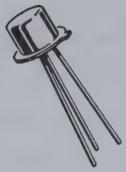
ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0)		$BV_{CEO(sus)}$	45	—	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 5 Vdc, I_B = 0)		I_{CEO}	—	0.010	µAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)		I_{CBO}	—	0.010	µAdc
(V_{CB} = 45 Vdc, I_E = 0, T_A = +150°C)			—	10	
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)		I_{EBO}	—	0.010	µAdc
ON CHARACTERISTICS					
DC Current Gain (1) (I_C = 10 µAdc, V_{CE} = 5 Vdc)	2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644	h_{FE}	50 100	300 300	—
(I_C = 10 µAdc, V_{CE} = 5 Vdc, T_A = -55°C)	2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		10 20	— —	
(I_C = 100 µAdc, V_{CE} = 5 Vdc)	2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		55 110	— —	
(I_C = 1 mAdc, V_{CE} = 5 Vdc)	2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		65 130	— —	
Collector-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 0.5 mAdc)		$V_{CE(sat)}$	—	1.0	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 0.5 mAdc)		$V_{BE(sat)}$	0.6	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)		f_T	35	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	8.0	pF
Input Impedance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)		h_{ib}	25	32	K ohms
Reverse Voltage Transfer Ratio (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)		h_{rb}	—	600	X 10^{-6}
Small-Signal Current Gain (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644	h_{fe}	65 130	600 600	—
Output Admittance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)		h_{ob}	—	1.0	µmhos
Noise Figure (I_C = 10 µAdc, V_{CB} = 5 Vdc, R_S = 10k ohms, Bandwidth = 10 Hz to 15 kHz)		NF	—	4.0	dB
MATCHING CHARACTERISTICS					
DC Current Gain Ratio** (I_C = 10 µAdc, V_{CE} = 5 Vdc)	2N2639, 2N2642 2N2640, 2N2643	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 10 µAdc, V_{CE} = 5 Vdc)	2N2639, 2N2642 2N2640, 2N2643	$\|V_{BE1} - V_{BE2}\|$	— —	5.0 10	mVdc
Base Voltage Differential Temperature Gradient (I_C = 10 µAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C)	2N2639, 2N2642 2N2640, 2N2643	$\frac{\Delta\|V_{BE1} - V_{BE2}\|}{\Delta T_A}$	— —	10 20	µV/°C

(1) Pulse Test: Pulse Width = 300 µs; Duty Cycle ≤ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

2N2646 (SILICON)
2N2647



Silicon annular PN unijunction transistors designed for use in pulse and timing circuits, sensing circuits and thyristor trigger circuits.

CASE 22A
(TO-18 Modified)
(Lead 3 connected to case)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	300*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	2.0 **	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage	V_{B2B1}	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	^{o}C
Storage Temperature Range	T_{stg}	-65 to +150	^{o}C

* Derate 3.0 mW/^{o}C increase in ambient temperature. The total power dissipation (available power to Emitter and Base-Two) must be limited by the external circuitry.

** Capacitor discharge — 10 μF or less, 30 volts or less.

2N2646, 2N2647 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) (Note 1)	2N2646 2N2647	η	0.56 0.68	— —	0.75 0.82	—
Interbase Resistance (V_{B2B1} = 3 V, I_E = 0)		R_{BB}	4.7	7.0	9.1	K ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3 V, I_E = 0, T_A = -55°C to +125°C)		αR_{BB}	0.1	—	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) (Note 2)		$V_{EB1(sat)}$	—	3.5	—	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	—	15	—	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)	2N2646 2N2647	I_{EO}	— —	0.005 0.005	12 0.2	µA
Peak Point Emitter Current (V_{B2B1} = 25 V)	2N2646 2N2647	I_P	— —	1.0 1.0	5.0 2.0	µA
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) (Note 2)	2N2646 2N2647	I_V	4.0 8.0	6.0 10	— 18	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3)	2N2646 2N2647	V_{OB1}	3.0 6.0	5.0 7.0	— —	Volts

NOTES

1. Intrinsic standoff ratio, η, is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop (≈0.5 V @ 10 µA)

2. Use pulse techniques: PW ≈ 300 µs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

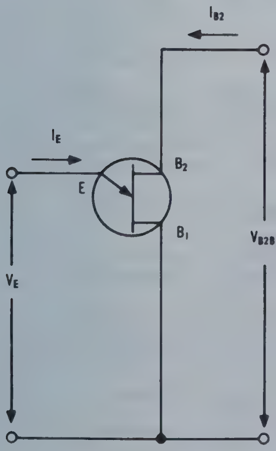


FIGURE 2 — STATIC EMITTER CHARACTERISTIC CURVES

(Exaggerated to Show Details)

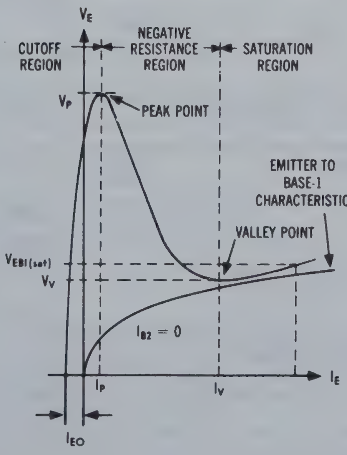
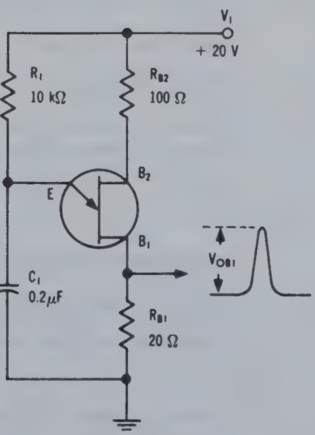


FIGURE 3 — V_{OB1} TEST CIRCUIT

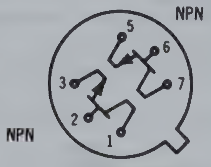
(Typical Relaxation Oscillator)



2N2652 (SILICON)
2N2652A

Dual NPN silicon transistors for use as a differential amplifier.

Case 654-04
TO-78



PINS 4 AND 8 OMITTED
Pin Connections, Bottom View

All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	100		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	500		mAdc
Operating Junction Temperature Range	T_J	-65 to +200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.6	Watt
Derate above 25°C		1.72	3.43	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.0	2.0	Watts
T_C = 100°C		0.57	1.14	Watt
Derate above 25°C		5.7	11.4	mW/°C

2N2652, 2N2652A (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 20 mAdc, I_B = 0)	BV_{CEO}	60	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	100	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0) 2N2652		-	0.010	
2N2652A		-	0.002	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C) 2N2652		-	15	
2N2652A		-	10	
Emitter Cutoff Current	I_{EBO}			μAdc
(V_{BE} = 5.0 Vdc, I_C = 0) 2N2652		-	0.010	
2N2652A		-	0.002	
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		35	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		50	200	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)		15	-	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	-	1.2	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0, 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	1.0	10.5	k ohms
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	35	ohms
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	50	300	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	4.0	50	μmhos
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, B. W. = 1.0 Hz, f = 1.0 kHz)	NF		8.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**			-
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2652		0.85	1.0	
2N2652A		0.9	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2652		0.85	1.0	
2N2652A		0.9	1.0	
Base Voltage Differential	$\|V_{BE1}-V_{BE2}\|$			mVdc
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		-	3.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		-	3.0	
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +125°C)	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	-	10	μV/°C

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

** The lowest of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

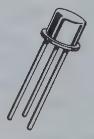
2N2696 (SILICON)
2N2927

PNP SILICON ANNULAR TRANSISTORS

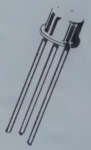
. . . designed for use in medium-speed, non-saturated switching applications.

- High Collector-Emitter Breakdown Voltage —
  BV_{CEO} = 25 Vdc @ I_C = 100 μAdc
- High Collector-Base Breakdown Voltage —
  BV_{CBO} = 25 Vdc @ I_C = 100 μAdc

PNP SILICON SWITCHING TRANSISTORS



2N2696



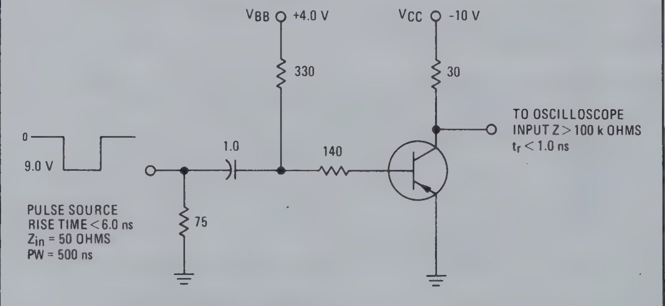
2N2927

MAXIMUM RATINGS

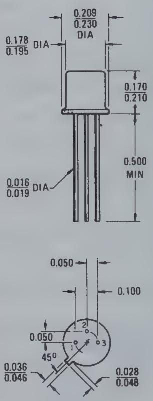
Rating	Symbol	2N2696	2N2927	Unit
Collector-Emitter Voltage	V_{CEO}	25		Vdc
Collector-Base Voltage	V_{CB}	25		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current — Continuous	I_C	500		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	0.8 4.56	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.85	3.0 17.1	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*Indicates JEDEC Registered Data.

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


VBB +4.0 V
VCC -10 V
330
30
0
9.0 V
1.0
140
75
TO OSCILLOSCOPE
INPUT Z > 100 k OHMS
tr < 1.0 ns
PULSE SOURCE
RISE TIME < 6.0 ns
Zin = 50 OHMS
PW = 500 ns

2N2696

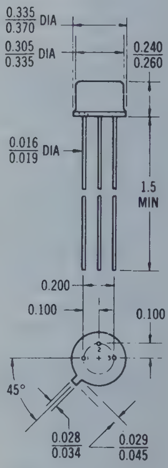

0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

Pin 1. Emitter
2. Base
3. Collector

Collector connected to case

CASE 22 (1)
(TO-18)

2N2927


0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
0.016
0.019
DIA
1.5
MIN
0.200
0.100
0.100
45°
0.028
0.034
0.029
0.045
1
2
3

Pin 1. Emitter
2. Base
3. Collector

Collector connected to case

CASE 31 (1)
(TO-5)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage**		BV_{CEO}			Vdc
(I_C = 100 μAdc, I_B = 0)	2N2927		25	–	
(I_C = 10 mAdc, I_B = 0)	2N2696		25	–	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	25	–	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	2N2927	I_{CES}	–	25	nAdc
Collector Cutoff Current		I_{CBO}			
(V_{CB} = 10 Vdc, I_E = 0)			–	0.025	μAdc
(V_{CB} = 10 Vdc, I_E = 0, T_A = 150°C)			–	5.0	μAdc
(V_{CB} = 15 Vdc, I_E = 0, T_A = 125°C)	2N2927		–	5.0	μAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)		I_{EBO}	–	100	μAdc
Base Current (V_{CE} = 15 Vdc, V_{BE} = 0)	2N2927	I_B	–	25	nAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			30	130	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)			12	–	
(I_C = 300 mAdc, V_{CE} = 2.0 Vdc)(1)			20	–	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)			–	0.25	
(I_C = 300 mAdc, I_B = 30 mAdc)			–	1.0	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)			–	1.1	
(I_C = 300 mAdc, I_B = 30 mAdc)			–	2.0	
Base-Emitter On Voltage (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	2N2927	$V_{BE(on)}$	–	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	–	20	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{ie}	–	1500	ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{re}	–	26	$X 10^{-4}$
Small-Signal Current Gain		h_{fe}			–
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)			25	180	
(I_C = 50 mAdc, V_{CE} = 3.0 Vdc, f = 100 MHz)			1.0	–	
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	–	1200	μmhos
SWITCHING CHARACTERISTICS					
Turn-On Time	(V_{CC} = 10 Vdc, $I_C \approx$ 300 mAdc, $I_{B1} \approx$ 30 mAdc) (See Figure 1)	t_{on}	–	75	ns
Turn-Off Time	(V_{CC} = 10 Vdc, $I_C \approx$ 300 mAdc, $I_{B1} = I_{B2} \approx$ 30 mAdc) (See Figure 1)	t_{off}	–	170	ns

*Indicates JEDEC Registered Data.

**Motorola Guarantees this data in addition to JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

2N2710 (SILICON)

CASE 22
(TO-18)

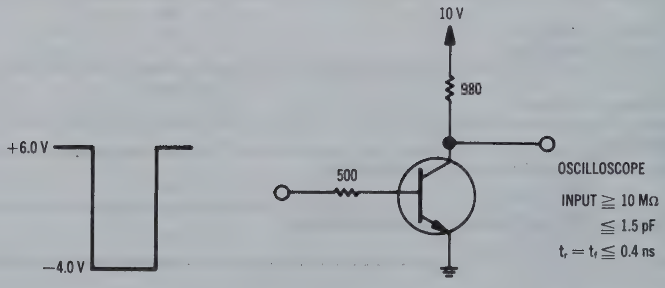
Collector connected to case

NPN silicon transistor primarily designed for high-speed, low-power saturated switching applications for industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current-Continuous	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.1	W mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	1.2	W
Operating Junction Temperature Range	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT

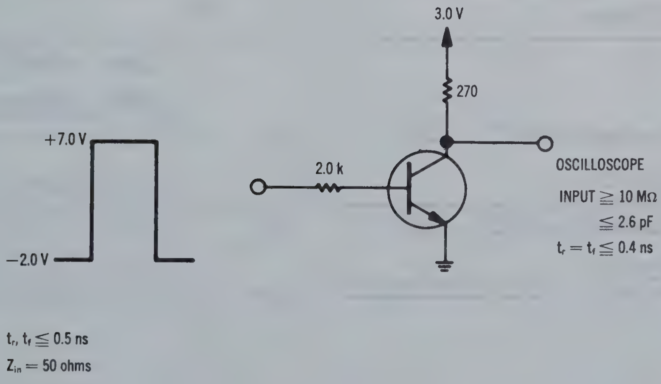


$t_r, t_f ≦ 0.5$ ns
$Z_{in} = 50$ ohms

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	20	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector-Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 VDC, I_E = 0, T_A = +150°C)	I_{CBO}	- -	0.03 30	μAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	40 40	- -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	- -	0.25 0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	- -	0.9 1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	500	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 4.0 MHz)	C_{ob}	-	4.0	pF
Turn-On Time (Figure 2) (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc)	t_{on}	-	20	ns
Turn-Off Time (Figure 2) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	35	ns
Charge-Storage Time (Figure 1) (V_{CC} = 10 Vdc, I_C = I_{B1} = I_{B2} = 10 mAdc)	t_s	-	15	ns

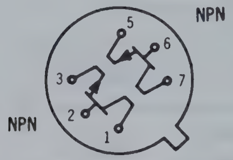
FIGURE 2 — TURN ON AND TURN OFF TIME TEST CIRCUIT



2N2720 (SILICON)
2N2721

Case 654-04
TO-78

Dual NPN silicon transistors for small-signal, low-power differential amplifier applications.



PINS 4 AND 8 OMITTED
Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	80		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	40		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.3 1.71	0.6 3.4	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.6 3.4	1.2 6.8	Watts mW/°C

2N2720, 2N2721 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	60	-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)		I_{CEO}	-	10	nAdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 150° C)		I_{CBO}	- -	0.01 10	µAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	10	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 100 µAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)		h_{FE}	30 35 42	120 - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{BE(sat)}$	0.65	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)		f_T	80	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	-	6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{rb}	-	500	X 10^{-6}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		h_{fe}	30	200	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	1.0	µmhos
MATCHING CHARACTERISTICS					
DC Current Gain Ratio** (I_C = 100 µAdc, V_{CE} = 5.0 Vdc)	2N2720 2N2721	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	-
Base Voltage Differential (I_C = 100 µAdc, V_{CE} = 5.0 Vdc)	2N2720 2N2721	$\lvert V_{BE1}-V_{BE2}\rvert$	- -	5.0 10	mVdc
Base Voltage Differential Gradient (I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25° C) (I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125° C)	2N2720 2N2721 2N2720 2N2721	$\Delta\left(V_{BE1}-V_{BE2}\right)$	- - - -	0.8 1.6 1.0 2.0	mV

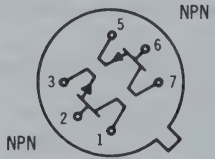
(1) Pulse Test: Pulse Width = 300 µs, Duty Cycle = 2%

** The lower of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

2N2722 (SILICON)

Case 654-04
TO-78

Dual NPN silicon transistor for small-signal, low-power differential amplifier applications.



PINS 4 AND 8 OMITTED
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	40		mAdc
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.6	Watt
Derate above 25°C		1.7	3.4	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.6	1.2	Watts
Derate above 25°C		3.4	6.8	mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ⁽¹⁾ (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	45	-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)	I_{CEO}	-	2.0	nAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.001 1.0	μAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc) (I_C = 10 μAdc, V_{CE} = 5.0 Vdc) (I_C = 0.1 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}	50 100 125	250 - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	0.65	0.85	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	100	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	600	X 10^{-6}
Small-Signal Current Gain (I_E = 0.1 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	100	700	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmhos
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_G = 10 k ohms, f = 10 Hz to 15.7 kHz)	NF	-	4.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)	h_{FE1}/h_{FE2}**	0.9	1.0	-
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	$\|V_{BE1} - V_{BE2}\|$	-	5.0	mVdc
Base Voltage Differential Gradient (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C) (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C)	$\Delta(V_{BE1} - V_{BE2})$	- -	0.8 1.0	mVdc

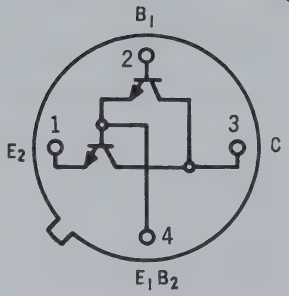
(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2.0%.

** The lower of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

2N2723 thru 2N2725 (SILICON)

CASE 20(8)
(TO-72)

Two NPN silicon annular transistors connected as a darlington amplifier, and designed for applications requiring very high gain.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N2723 2N2724	2N2725	Unit
Collector Emitter Voltage	V_{CE2O}	60	45	Vdc
Collector-Base Voltage	V_{CB1}	80	45	Vdc
Emitter-Base Voltage	V_{E2B1}	12	10	Vdc
Collector Current	I_C	40	30	mAdc
Total Device Dissipation @ T_A = 25°C	P_D	0.5		Watt
Derate above 25°C		2.9		mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.8		Watts
T_C = 100°C		1.0		Watt
Derate above 25°C		10.5		mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

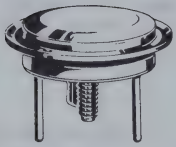
2N2723 thru 2N2725 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_{B1} = 0) 2N2723, 2N2724 2N2725	BV_{CE2O}	60 45	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_{E2} = 0) 2N2723, 2N2724 2N2725	BV_{CB1O}	80 45	- -	Vdc
Emitter-Base Breakdown Voltage (I_{E2} = 10 μAdc, I_C = 0) 2N2723, 2N2724 2N2725	BV_{E2B1O}	12 10	- -	Vdc
Collector Cutoff Current (V_{CB1} = 60 Vdc, I_E = 0) 2N2723, 2N2724 (V_{CB1} = 60 Vdc, I_E = 0, T_A = 150°C) 2N2723, 2N2724 (V_{CB1} = 30 Vdc, I_E = 0) 2N2725 (V_{CB1} = 30 Vdc, I_E = 0, T_A = 150°C) 2N2725	I_{CB1O}	- - - -	0.01 10 0.002 2.0	μAdc
Emitter Cutoff Current (V_{B1E2} = 10 Vdc, I_C = 0) 2N2723, 2N2724 (V_{B1E2} = 6.0 Vdc, I_C = 0) 2N2725	I_{E2B1O}	- -	10 1.0	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, I_{B2} = 0) 2N2723 2N2724 (I_C = 100 μAdc, V_{CE2} = 5.0 Vdc, I_{B2} = 0) 2N2725	h_{FE}	2000 7000 2000	10,000 50,000 10,000	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	$V_{CE2(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	$V_{BE2(sat)}$	-	1.7	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (Each Unit) (I_C = 10 mAdc, V_{CE1} or V_{CE2} = 10 Vdc, f = 20 MHz)	f_T	100	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 140 kHz) 2N2723, 2N2724	C_{ob1}	-	10	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz) 2N2723 2N2724 (I_C = 10 μAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz) 2N2725	h_{fe}	1500 5000 1500	15,000 60,000 15,000	-
Noise Figure (Input Stage Only) (I_C = 50 μAdc, V_{CE} = 5.0 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2723 (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2724 (I_C = 3.0 μAdc, V_{CE} = 5.0 Vdc, R_S = 30 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2725	NF	- - -	10 6.0 6.0	dB

(1) Pulse Test: Pulse Width ≤12 ms, Duty Cycle ≤2.0 %.

2N2728 (GERMANIUM)



CASE 7

PNP germanium high-current power transistors especially designed for switching and power converter circuit operating from low-voltage power sources such as solar cells, thermo-electric generators, sea cells, fuel cells, and 1.5-volt batteries.

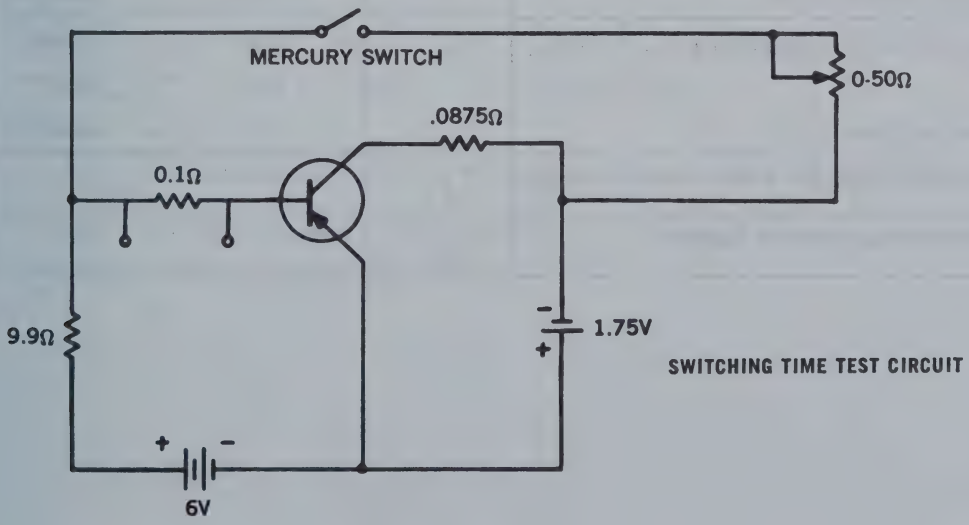
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	5.0	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (continuous)	I_C	50	Adc
Base Current (continuous)	I_B	10	Adc
Total Device Dissipation @ 25°C Case Temperature	P_D	170	Watts
Operating Temperature	T_J	+110	°C
Storage Temperature	T_{stg}	-65 to +110	°C
Thermal Resistance (Junction to Case)	θ_{JC}	0.5	°C/W

ELECTRICAL CHARACTERISTICS

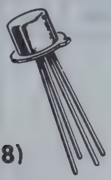
Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current $V_{CE} = 15$ V, $V_{BE} = 1$ V $V_{CE} = 10$ V, $V_{BE} = 1$ V, $T_C = 100°C$	I_{CEX}	- -	- -	10 35	mAdc
Emitter-Base Cutoff Current $V_{EB} = 15$ V	I_{EBO}	-	-	10	mAdc
Emitter Floating Potential $V_{CB} = 15$ V, $I_E = 0$	V_{EBF}	-	-	0.5	Vdc
Collector-Emitter Breakdown Voltage* $I_C = 500$ mA, $I_B = 0$	BV_{CEO}	5.0	10	-	V
DC Current Transfer Ratio $I_C = 20$ A, $V_{CE} = 2$ V	h_{FE}	40	-	130	-
Collector-Emitter Saturation Voltage $I_C = 50$ A, $I_B = 5$ A	$V_{CE(sat)}$	-	0.075	0.1	Vdc
Base-Emitter Voltage $I_C = 50$ A, $I_B = 5$ A	$V_{BE(sat)}$	-	0.85	1.0	Vdc
Common Emitter Cutoff Frequency $I_C = 20$ A, $V_{CE} = 2$ V	$f_{\alpha e}$	3.0	4.5	-	kHz
Rise Time $I_C = 20$ A, $V_{CC} = 1.75$ V, $I_{B(on)} = 2$ A	t_r	-	18	25	µs
Storage Time $V_{BE} = 6$ V, $R_{be} = 10\ \Omega$	t_s	-	15	20	µs
Fall Time $V_{BE} = 6$ V, $R_{be} = 10\ \Omega$	t_f	-	10	15	µs

* To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.



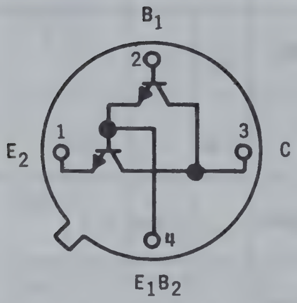
SWITCHING TIME TEST CIRCUIT

2N2785 (SILICON)



CASE 20(8)
(TO-72)

Two NPN silicon annular transistors connected as a darlington amplifier, and designed for applications requiring very high gain.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

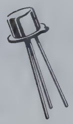
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE2O}	40	Vdc
Collector-Base Voltage	V_{CB1}	60	Vdc
Emitter-Base Voltage	V_{E2B1}	15	Vdc
(Pin 4 to Pin 2)		7.5	Vdc
Total Device Dissipation @ T_A = 25°C	P_D	0.5	Watt
Derate above 25°C		3.33	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.8	Watts
T_C = 100°C		1.0	Watt
Derate above 25°C		10	mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

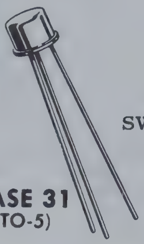
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 20 mAdc, I_{B1} = 0)	BV_{CE2O}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_{E2} = 0)	BV_{CB1O}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_{E2} = 100 μAdc, I_C = 0)	BV_{E2B1O}	15	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0)	I_{CEO}	-	500	nAdc
Collector Cutoff Current (V_{CB1} = 30 Vdc, I_E = 0) (V_{CB1} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CB1O}	- -	0.05 10	μAdc
Emitter Cutoff Current (V_{E2B1} = 5.0 Vdc, I_C = 0)	I_{E2B1O}	-	20	nAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 1.0 mAdc, V_{CE2} = 4.0 Vdc) (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc) (I_C = 100 mAdc, V_{CE2} = 5.0 Vdc)	h_{FE}	600 1200 2000	- - 20,000	-
Collector-Emitter Saturation Voltage (I_C = 15 mAdc, I_{B1} = 3.0 mAdc)	$V_{CE2(sat)}$	-	1.0	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 10 MHz)	f_T	10	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 1.0 MHz)	C_{ob1}	-	30	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB1} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	30	80	Ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	10	x 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	600	-	-
Output Admittance (I_C = 1.0 mAdc, V_{CB1} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.5	μmhos

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N2800 (SILICON)
2N2801
2N2837
2N2838



CASE 22
(TO-18)



CASE 31
(TO-5)

2N2837
2N2838

2N2800
2N2801

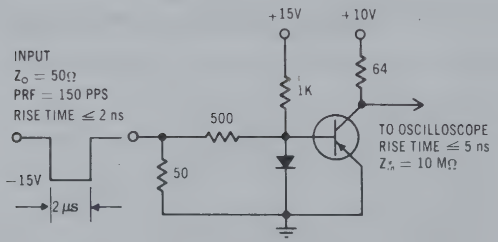
Collector connected to case

PNP silicon annular transistors for medium-speed switching applications.

MAXIMUM RATINGS

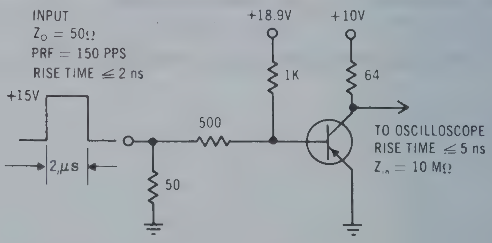
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Vdc
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	800	mA
Total Device Dissipation @ 25°C Ambient Temperature 2N2800, 2N2801 – TO-5 Derating Factor Above 25°C 2N2837, 2N2838 – TO-18 Derating Factor Above 25°C	P_D	 0.8 4.57 0.5 2.86	 Watt mW/°C Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature 2N2800, 2N2801 – TO-5 Derating Factor Above 25°C 2N2837, 2N2838 – TO-18 Derating Factor Above 25°C	P_D	 3.0 17.3 1.8 10.3	 Watts mW/°C Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C

DELAY AND RISE TIME TEST CIRCUIT



+15V
+10V
INPUT
Z₀ = 50Ω
PRF = 150 PPS
RISE TIME ≤ 2 ns
−15V
2 μs
500
50
1K
64
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Zᵢₙ = 10 MΩ

STORAGE AND FALL TIME TEST CIRCUIT



INPUT
Z₀ = 50Ω
PRF = 150 PPS
RISE TIME ≤ 2 ns
+18.9V
+10V
+15V
2 μs
500
50
1K
64
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Zᵢₙ = 10 MΩ

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	50	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	35	-	Vdc
Collector Cutoff Current (V_{CE} = 25 Vdc, V_{BE} = 0.5 Vdc)	I_{CEX}	-	100	nAdc
Base Cutoff Current (V_{CE} = 25 Vdc, V_{BE} = 0.5 Vdc)	I_{BL}	-	100	nAdc
DC Forward Current Transfer Ratio	h_{FE}			-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)				
2N2800, 2N2837		20	-	
2N2801, 2N2838		30	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)(1)				
2N2800, 2N2837		30	90	
2N2801, 2N2838		75	225	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)(1)				
2N2800, 2N2837		15	-	
2N2801, 2N2838		30	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)(1)				
2N2800, 2N2837		25	-	
2N2801, 2N2838		40	-	
Collector Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	1.2	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	1.3	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	1.8	
Output Capacitance (V_{CB} = 10 Vdc, f = 100 kHz)	C_{ob}	-	25	pF
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	120	-	MHz

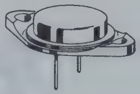
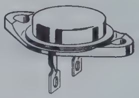
SWITCHING CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Typical	Maximum	Unit
Delay Time	t_d	9	25	ns
Rise Time	t_r	25	45	ns
Storage Time	t_s	100	225	ns
Fall Time	t_f	30	45	ns

(1) Pulse Test: Pulse Width ≦ 300 μs, duty cycle ≦ 2%

2N2832 (GERMANIUM)
2N2833
2N2834

PNP germanium transistors for switching and amplifier applications.

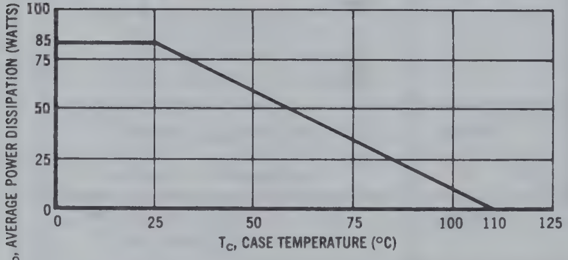
 **CASE 11A** (TO-3 modified) Collector connected to case	 **CASE 4-04** (TO-41)

For units with solder lugs attached, specify device MP2832 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N2832	2N2833	2N2834	Unit
Collector-Emitter Voltage	V_{CEO}	50	75	100	Vdc
Collector-Base Voltage	V_{CB}	80	120	140	Vdc
Emitter-Base Voltage	V_{EB}	2.0			Vdc
Collector Current - Continuous	I_C	20			Adc
Base Current	I_B	5.0			Adc
Total Device Dissipation @ T_C = 25° C	P_D	85			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			

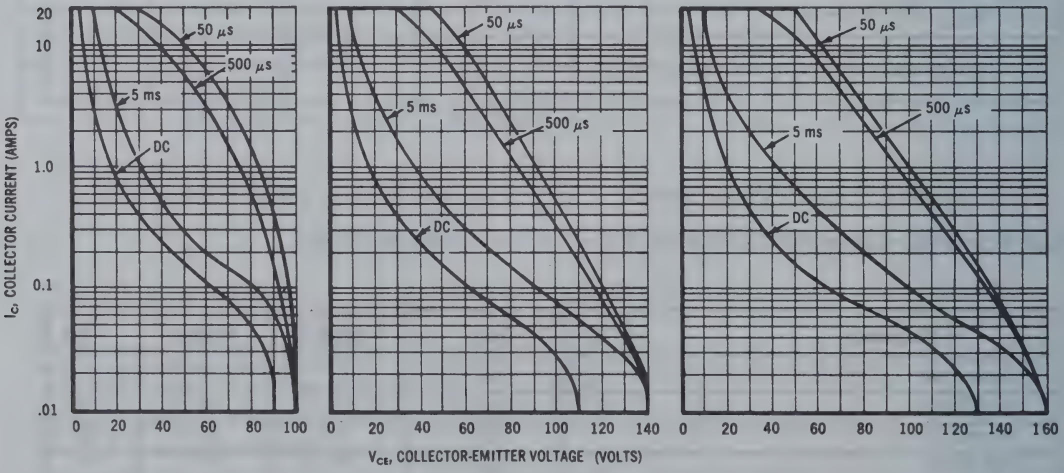
FIGURE 1 — POWER DERATING CURVE



THESE TRANSISTORS ARE ALSO SUBJECT TO SAFE AREA CURVES AS INDICATED BY FIGURES 2, 3, 4. BOTH LIMITS ARE APPLICABLE AND MUST BE OBSERVED

SAFE OPERATING AREAS

FIGURE 2 — 2N2832 FIGURE 3 — 2N2833 FIGURE 4 — 2N2834



The Safe Operating Area Curves indicate the I_C - V_{CE} limits below which the devices will not go into secondary breakdown. As secondary breakdown is independent of temperature and duty cycle, these curves can be used as long as the average power derating curve (Figure 1) is also taken into consideration to insure operation below the maximum junction temperature.

2N2832 thru 2N2834 (Continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage(1)		$BV_{CEO(sus)}$				Volts
(I_C = 100 mAdc, I_B = 0)	2N2832		50	-	-	
	2N2833		75	-	-	
	2N2834		100	-	-	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 50 mAdc, I_C = 0)			2.0	-	-	
Floating Potential*		V_{EBF}*				Volts
(V_{CB} = 80 Vdc, I_E = 0)	2N2832		-	-	0.5	
(V_{CB} = 120 Vdc, I_E = 0)	2N2833		-	-	0.5	
(V_{CB} = 140 Vdc, I_E = 0)	2N2834		-	-	0.5	
Collector Cutoff Current*		I_{CES}*				mAdc
(V_{CE} = 100 Vdc, V_{BE} = 0)	2N2832		-	-	20	
(V_{CE} = 140 Vdc, V_{BE} = 0)	2N2833		-	-	20	
(V_{CE} = 160 Vdc, V_{BE} = 0)	2N2834		-	-	20	
Collector Cutoff Current**		I_{CEX}**				mAdc
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2832		-	-	40	
(V_{CE} = 75 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2833		-	-	40	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2834		-	-	40	
Collector Cutoff Current*		I_{CBO}*				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	0.3	
(V_{CB} = 80 Vdc, I_E = 0)	2N2832		-	-	10	
(V_{CB} = 120 Vdc, I_E = 0)	2N2833		-	-	10	
(V_{CB} = 140 Vdc, I_E = 0)	2N2834		-	-	10	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)			50	75	-	
(I_C = 10 Adc, V_{CE} = 2.0 Vdc)			25	-	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 1.0 Adc, I_B = 100 mAdc)			-	-	0.15	
(I_C = 10 Adc, I_B = 1.0 Adc)			-	-	0.30	
(I_C = 20 Adc, I_B = 2.0 Adc)			-	-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 1.0 Adc, I_B = 100 mAdc)			-	-	0.6	
(I_C = 10 Adc, I_B = 1.0 Adc)			-	-	0.75	
(I_C = 20 Adc, I_B = 2.0 Adc)			-	-	1.0	
DYNAMIC CHARACTERISTICS						
Small Signal Current Gain		h_{fe}				-
(I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 5.0 MHz)			2.0	3.5	-	
Rise Time		t_r	-	2.0	4.0	μs
Storage Time		t_s	-	3.0	6.0	μs
Fall Time		t_f	-	1.0	2.5	μs

*SWEEP TEST: 1/2 Sine Wave, 60 Hz min.

(1) PULSE TEST: Pulse Width = 1.0 ms, 2.0% Duty Cycle.

FIG 5 — BASE-EMITTER SATURATION VOLTAGE VARIATIONS

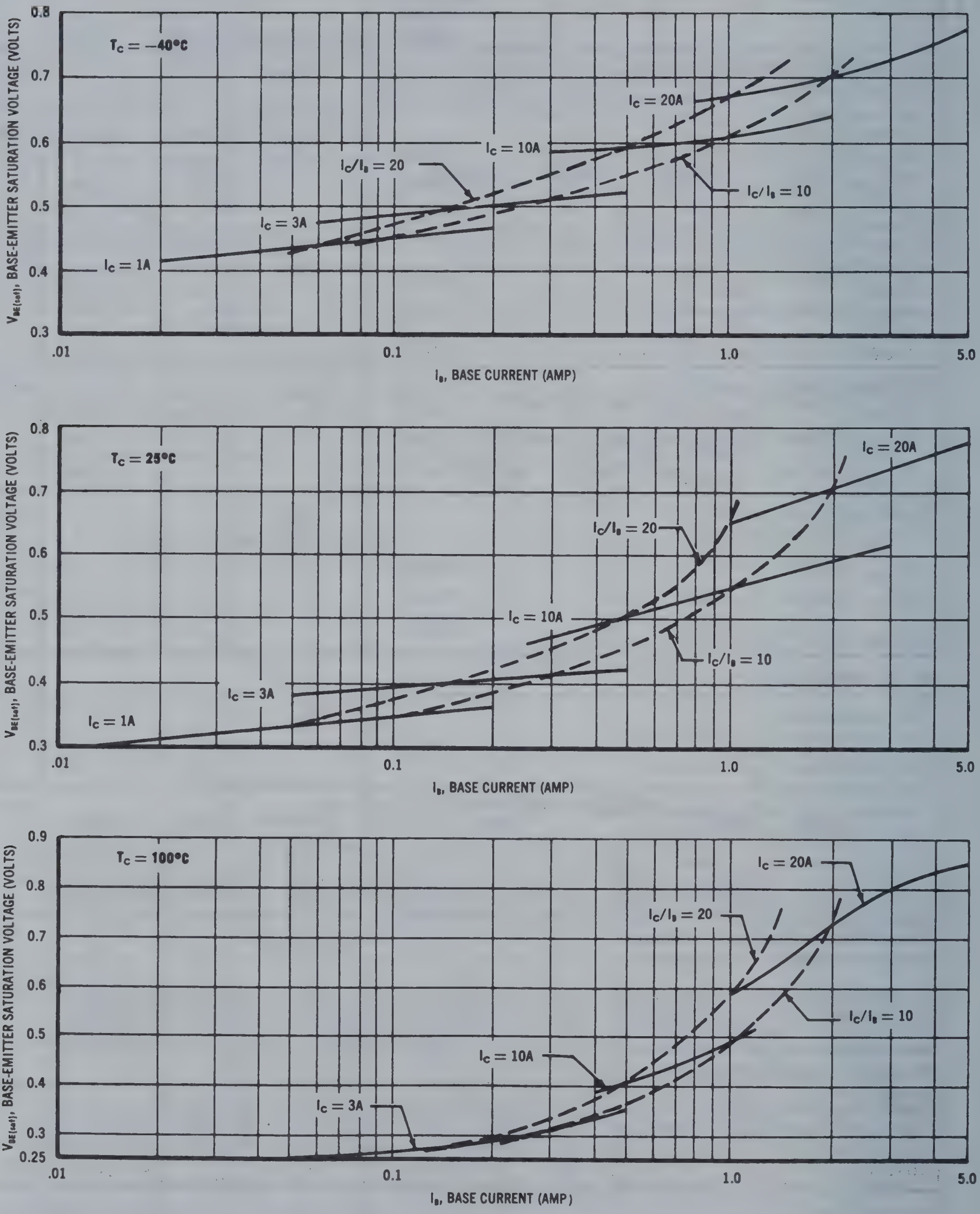


FIG 6 — COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

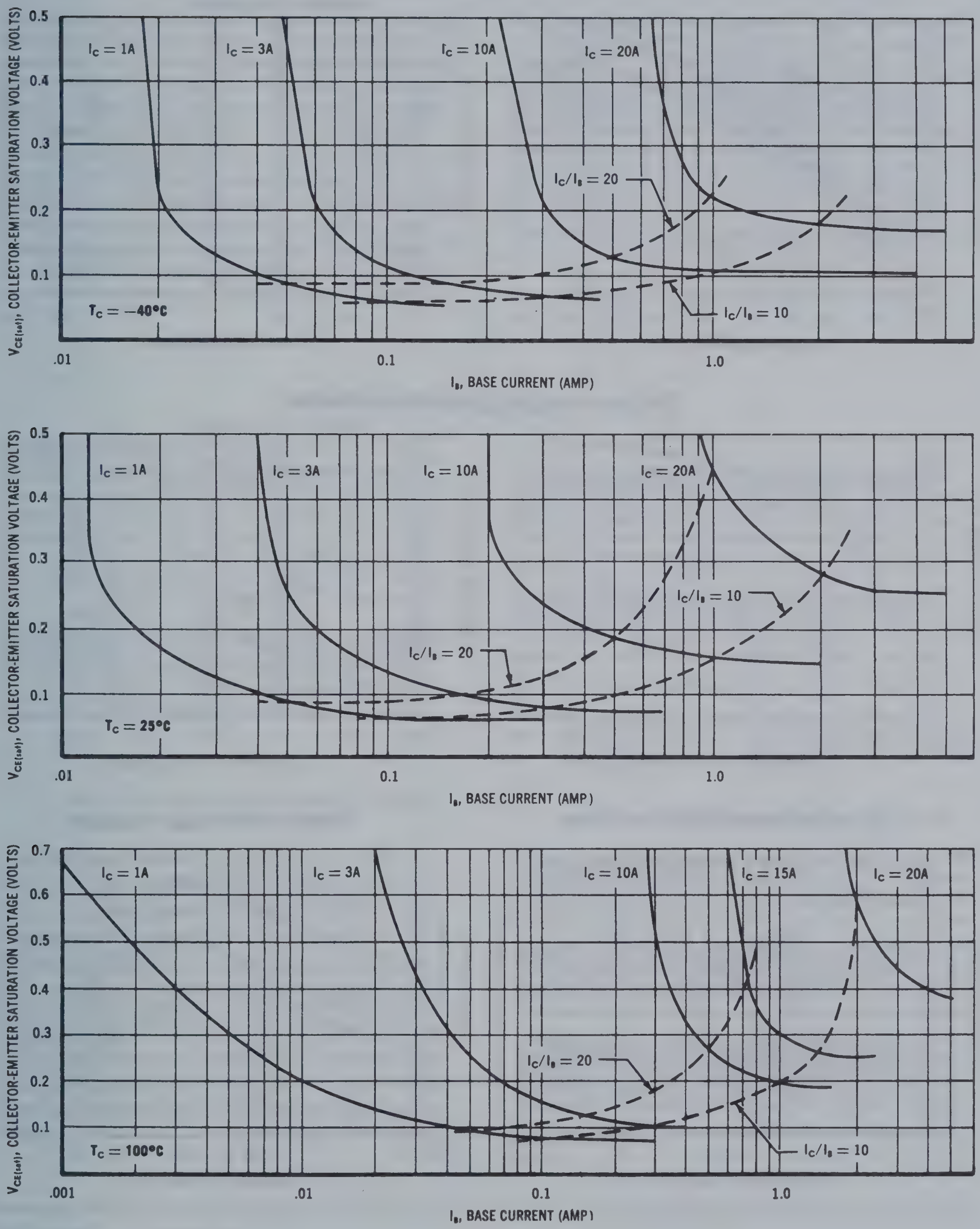


FIGURE 7 — CURRENT VARIATIONS

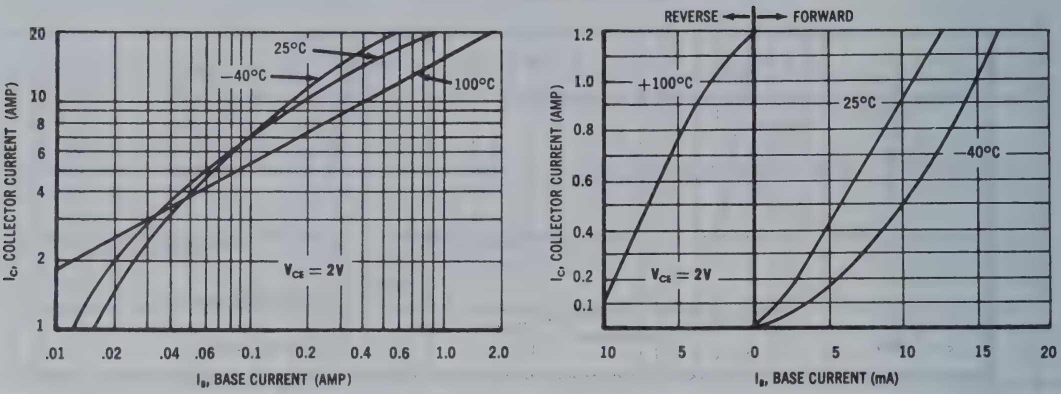


FIGURE 8 — COLLECTOR CURRENT-VOLTAGE VARIATION

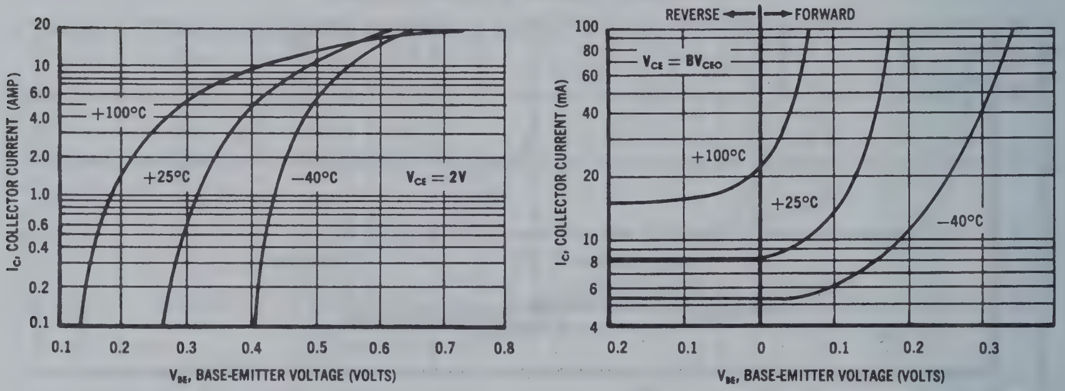


FIG 9 — BASE CURRENT-VOLTAGE VARIATIONS

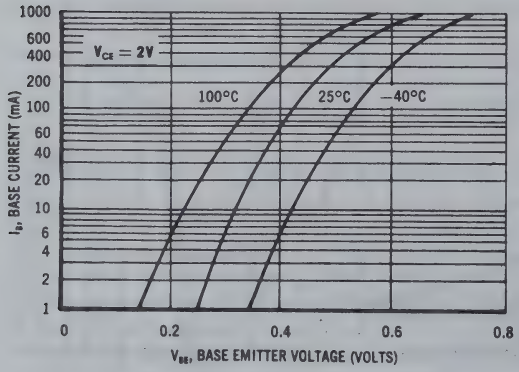


FIGURE 10 CURRENT-GAIN VARIATIONS

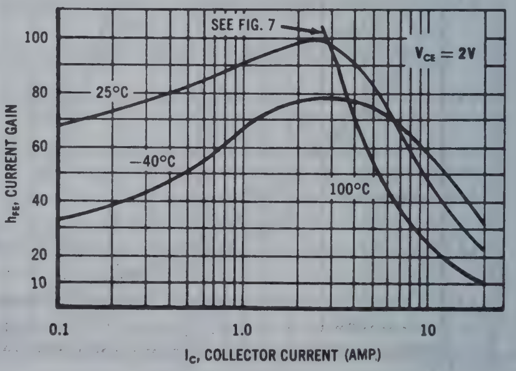


FIG 11 — RISE and FALL TIME vs COLLECTOR CURRENT

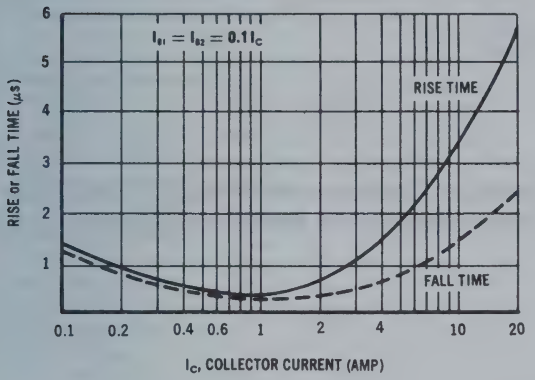


FIG 12 — STORAGE TIME vs COLLECTOR CURRENT

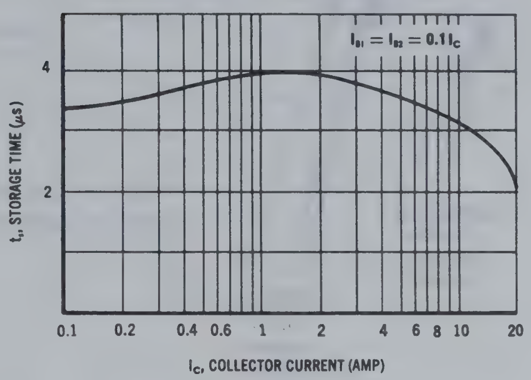
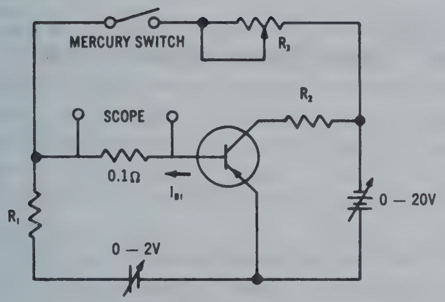


FIG 13 — SWITCHING TIME TEST CIRCUIT



Characteristic	Sym	Max	Unit
Rise Time	t_r	4	μs
Storage Time	t_s	6	μs
Fall Time	t_f	2.5	μs

ADJUST R_1, R_2, R_3, for $I_{B1} = I_{B2} = 0.1 I_C$

PULSE CONDITIONS; I_C = 5 AMP, I_{B1} = 0.5 AMP

Switching times shown are for constant current drive conditions. Faster times can be realized by the use of a lower source impedance or a speed-up capacitor. See Chapter 5 of the Motorola Switching Handbook for a more detailed explanation.

FIG 14 — CURRENT GAIN — BANDWIDTH PRODUCT vs COLLECTOR CURRENT

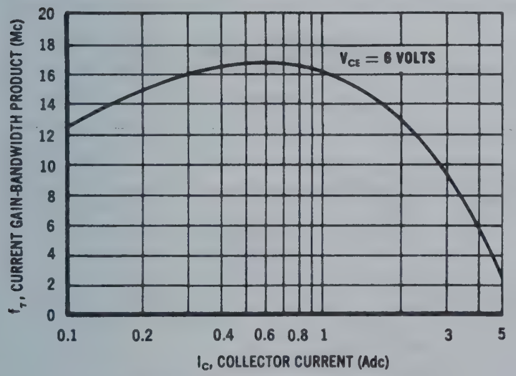
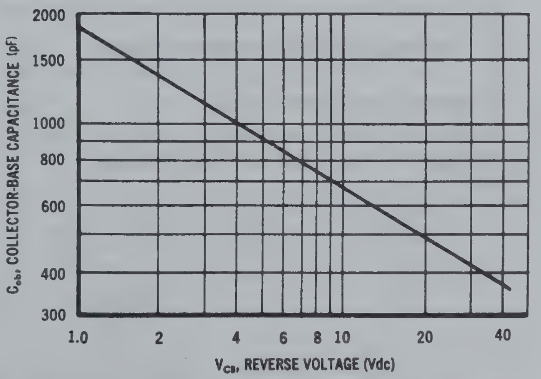


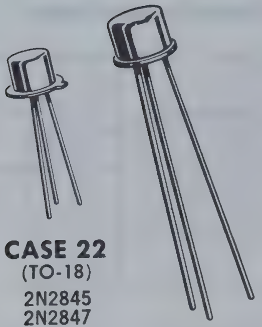
FIG 15 — OUTPUT CAPACITANCE vs REVERSE VOLTAGE



2N2837, 2N2838

For Specifications, See 2N2800 Data.

2N2845 thru 2N2848 (SILICON)



CASE 22
(TO-18)
2N2845
2N2847

CASE 31
(TO-5)
2N2846
2N2848

NPN silicon annular transistors designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2845	2N2846	2N2847	2N2848	Unit
Collector-Emitter Voltage*	V_{CEO}*	30	30	20	20	Vdc
Collector-Base Voltage	V_{CB}	60	60	60	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	5.0	5.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.1	800 4.6	360 2.1	800 4.6	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	3.0 17.2	1.2 6.9	3.0 17.2	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to 200				°C
Storage Temperature Range	T_{stg}	-65 to + 200				°C

*Applicable from 1 mA to 30 mA (Pulsed)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1)	$BV_{CEO(sus)}$			Vdc
(I_C = 30 mAdc, I_B = 0) 2N2845, 2N2846		30	—	
(I_C = 30 mAdc, I_B = 0) 2N2847, 2N2848		20	—	
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_{CES}	—	0.2	μAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	—	200	μAdc
Base Leakage Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_{BL}	—	0.2	μAdc
ON CHARACTERISTICS (1)				
DC Current Gain	h_{FE}			—
(I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N2845, 2N2846		30	120	
2N2847, 2N2848		40	140	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) 2N2845, 2N2846		20	—	
2N2847, 2N2848		30	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc) All Types		10	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc) All Types		—	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc) 2N2845, 2N2846		—	1.0	
2N2847, 2N2848		—	0.75	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		—	1.2	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	1.6	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	8.0	pF
Turn-On Time (Figure 1)	t_{on}			ns
(V_{CC} = 10 Vdc, I_C ≈ 150 mAdc, I_{B1} ≈ 15 mAdc) 2N2845, 2N2846		—	40	
(V_{CC} = 6 Vdc, I_C ≈ 150 mAdc, I_{B1} ≈ 15 mAdc) 2N2847, 2N2848		—	25	
Turn-Off Time (Figure 2)	t_{off}			ns
(V_{CC} = 10 Vdc, I_C ≈ 150 mAdc, I_{B1} ≈ I_{B2} ≈ 15 mAdc) 2N2845, 2N2846		—	40	
(V_{CC} = 6 Vdc, I_C ≈ 150 mAdc, I_{B1} ≈ I_{B2} ≈ 15 mAdc) 2N2847, 2N2848		—	40	

(1) **Pulse Test: Pulse Width = 300 μs; Duty Cycle = ≤ 2%**

FIGURE 1 — TURN-ON TIME TEST CIRCUIT

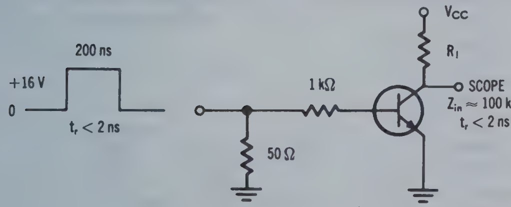
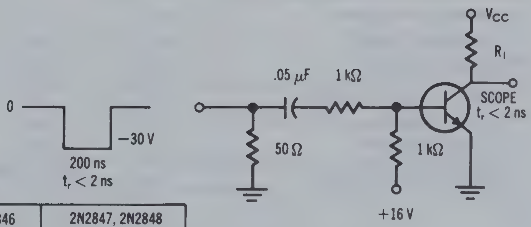


FIGURE 2 — TURN-OFF TIME TEST CIRCUIT



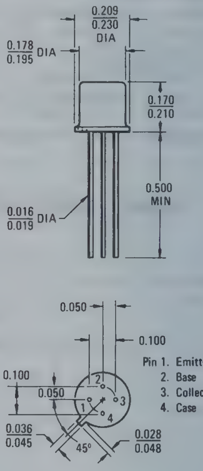
	2N2845, 2N2846	2N2847, 2N2848
V_{CC}	10 V	6 V
R_1	62 Ω	39 Ω

NPN SILICON RF SMALL-SIGNAL TRANSISTOR

. . . designed primarily for use in high-gain, low-noise amplifier, oscillator, and mixer applications. Can also be used in UHF converter applications.

- High Current-Gain—Bandwidth Product — f_T = 1.6 GHz (Typ) @ I_C = 8.0 mAdc
- Low Noise Figure — NF = 4.5 dB (Max) @ f = 450 MHz
- Low Collector-Base Time Constant — $r_b'C_c$ = 15 ps (Max) @ I_E = 2.0 mAdc
- Characterized with Scattering Parameters
- Ideal for Micro-Power Applications

NPN SILICON
RF SMALL-SIGNAL
TRANSISTOR


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
0.100
Pin 1. Emitter
2. Base
3. Collector
4. Case
0.100
0.050
1
2
3
4
0.036
0.045
45°
0.028
0.048

CASE 20 (10)
TO-72 PACKAGE

Active Elements Isolated from Case

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current — Continuous	I_C	40	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	200 1.14	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.

*ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage** ($I_C = 3.0$ mAdc, $I_B = 0$)	BV_{CEO}	15	–	–	Vdc
Collector-Base Breakdown Voltage ($I_C = 1.0$ μAdc, $I_E = 0$)	BV_{CBO}	30	–	–	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$)	BV_{EBO}	2.5	–	–	Vdc
Collector Cutoff Current ($V_{CB} = 15$ Vdc, $I_E = 0$)	I_{CBO}	–	–	0.01	μAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 3.0$ mAdc, $V_{CE} = 1.0$ Vdc)	h_{FE}	30	–	150	–
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product ① ($I_C = 5.0$ mAdc, $V_{CE} = 6.0$ Vdc, f = 100 MHz)	f_T	1000	–	1900	MHz
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 0.1 to 1.0 MHz)	C_{cb}	–	0.7	1.0	pF
Small-Signal Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 6.0$ Vdc, f = 1.0 kHz)	h_{fe}	50	–	220	–
Collector-Base Time Constant ($I_E = 2.0$ mAdc, $V_{CB} = 6.0$ Vdc, f = 31.9 MHz)	$r_b'C_c$	4.0	–	15	ps
Noise Figure (Figure 1)	NF				dB
($I_E = 0.1$ mAdc, $V_{CE} = 1.0$ Vdc, $R_S = 50$ ohms, f = 450 MHz) ②		–	5.8	–	
($I_C = 1.5$ mAdc, $V_{CE} = 6.0$ Vdc, $R_S = 50$ ohms, f = 450 MHz)		–	3.7	4.5	
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain (Figure 1)	G_{pe}				dB
($I_E = 0.1$ mAdc, $V_{CE} = 1.0$ Vdc, f = 450 MHz) ②		–	11	–	
($I_C = 1.5$ mAdc, $V_{CE} = 6.0$ Vdc, f = 450 MHz)		12.5	–	19	
Power Output (Figure 2) ($I_E = 12$ mAdc, $V_{CB} = 10$ Vdc, f = 500 MHz)	P_{out}	30	–	–	mW

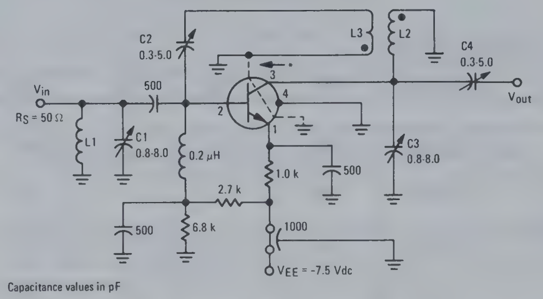
*Indicates JEDEC Registered Data.

**Motorola guarantees this data in addition to JEDEC Registered Data.

① f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

② Micro-Power Specifications.

FIGURE 1 – TEST CIRCUIT FOR NOISE FIGURE AND POWER GAIN


C2
0.3-5.0
L3
L2
C4
0.3-5.0
Vin
RS = 50 Ω
500
3
4
2
1
Vout
L1
C1
0.8-8.0
0.2 µH
1.0 k
500
C3
0.8-8.0
2.7 k
500
6.8 k
1000
VEE = -7.5 Vdc
Capacitance values in pF

L1, L2 – Silver-plated brass rod, 1-1/2″ long and 1/4″ dia. Install at least 1/2″ from nearest vertical chassis surface.

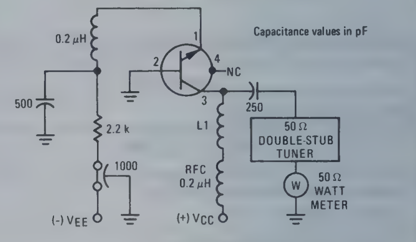
L3 – 1/2 turn #16 AWG wire, located 1/4″ from and parallel to L2.

* – External interlead shield to isolate collector lead from emitter and base leads.

Neutralization Procedure:

- (A) Connect 450-MHz signal generator (with $R_S = 50$ ohms) to input terminals of amplifier.
- (B) Connect 50-ohm RF voltmeter across output terminals of amplifier.
- (C) Apply V_{EE}, and with signal generator adjusted for 5 mV output from amplifier, tune C1, C3, and C4 for maximum output.
- (D) Interchange connections to signal generator and RF voltmeter.
- (E) With sufficient signal applied to output terminals of amplifier, adjust C2 for minimum indication at input.
- (F) Repeat steps (A), (B), and (C) to determine if retuning is necessary.

FIGURE 2 – TEST CIRCUIT FOR OSCILLATOR POWER OUTPUT


Capacitance values in pF
0.2 µH
1
2
4
NC
3
500
250
2.2 k
L1
50 Ω
DOUBLE-STUB
TUNER
1000
RFC
0.2 µH
W
50 Ω
WATT
METER
(-) VEE
(+) VCC

L1 – 3 turns #16 AWG wire, 3/8″ O.D. 1-1/4″ long.

FIGURE 3 – NOISE FIGURE versus FREQUENCY

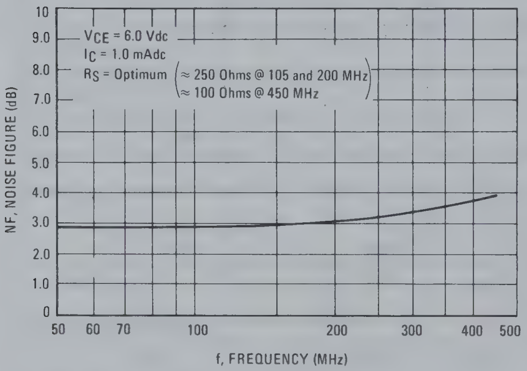


FIGURE 4 – NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT

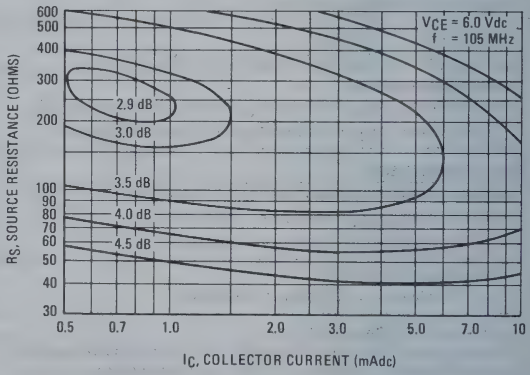


FIGURE 5 – NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT

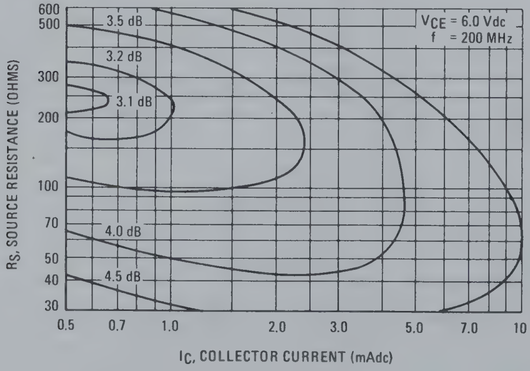


FIGURE 6 – CURRENT-GAIN–BANDWIDTH PRODUCT

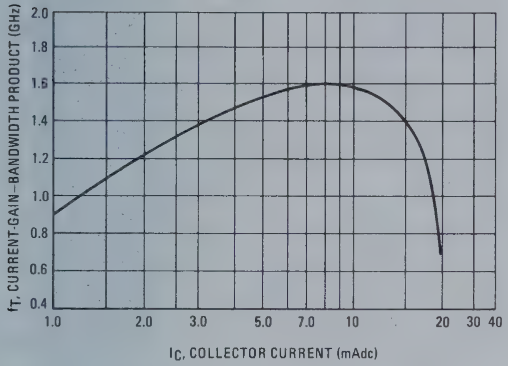


FIGURE 7 – NOISE FIGURE AND POWER GAIN versus COLLECTOR CURRENT

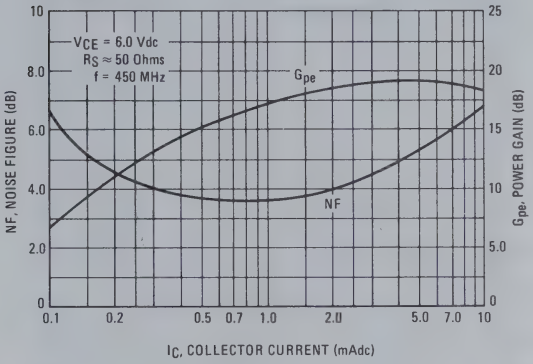


FIGURE 8 – INPUT ADMITTANCE versus FREQUENCY

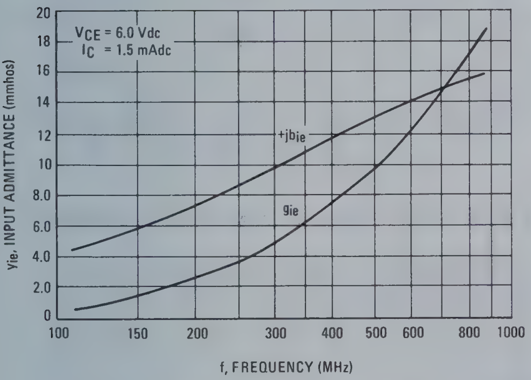


FIGURE 9 – OUTPUT ADMITTANCE versus FREQUENCY

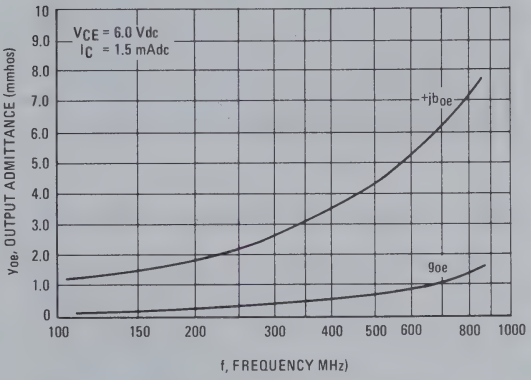


FIGURE 10 – FORWARD TRANSFER ADMITTANCE versus FREQUENCY

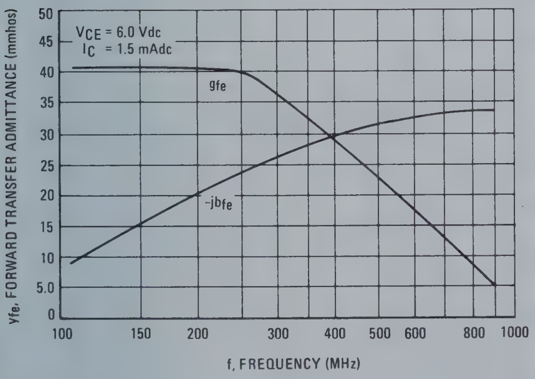


FIGURE 11 – REVERSE TRANSFER ADMITTANCE versus FREQUENCY

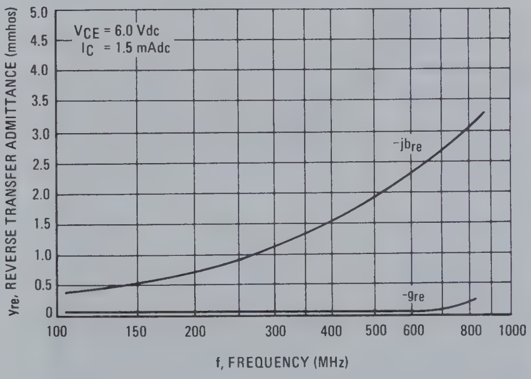


FIGURE 12 – S_{11}, INPUT REFLECTION COEFFICIENT

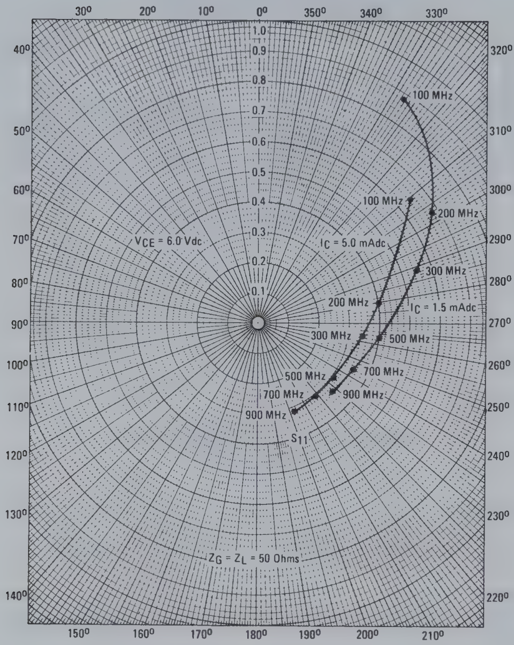


FIGURE 13 – S_{22}, OUTPUT REFLECTION COEFFICIENT

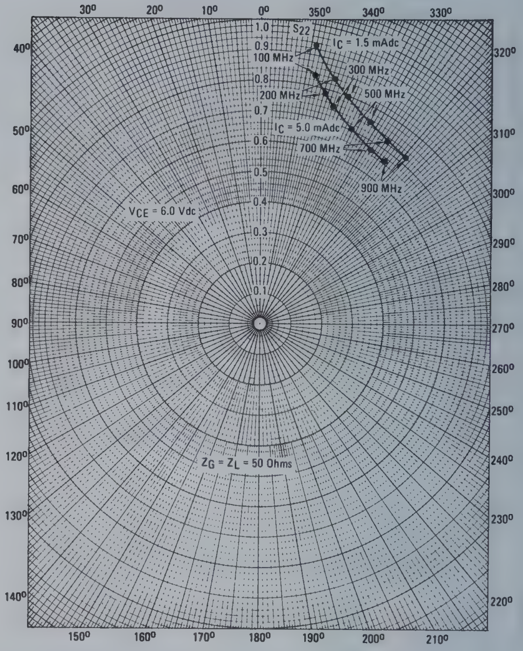


FIGURE 14 – S_{12}, REVERSE TRANSMISSION COEFFICIENT

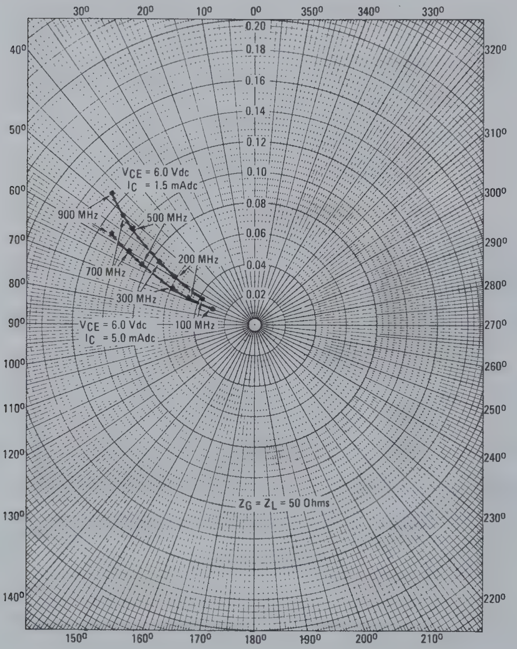


FIGURE 15 – S_{21}, FORWARD TRANSMISSION COEFFICIENT

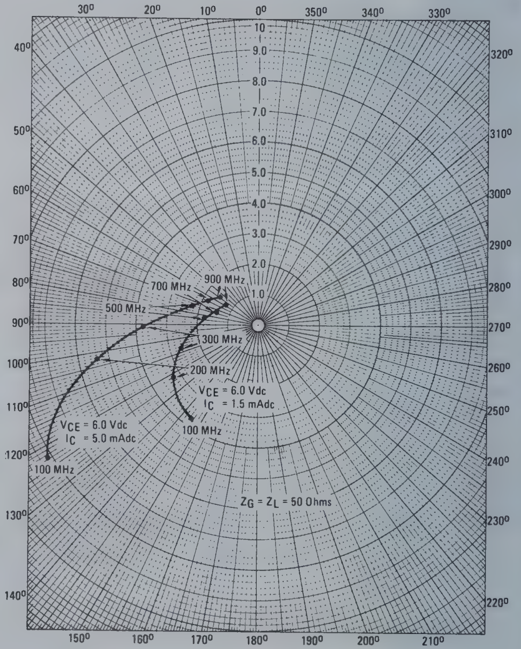
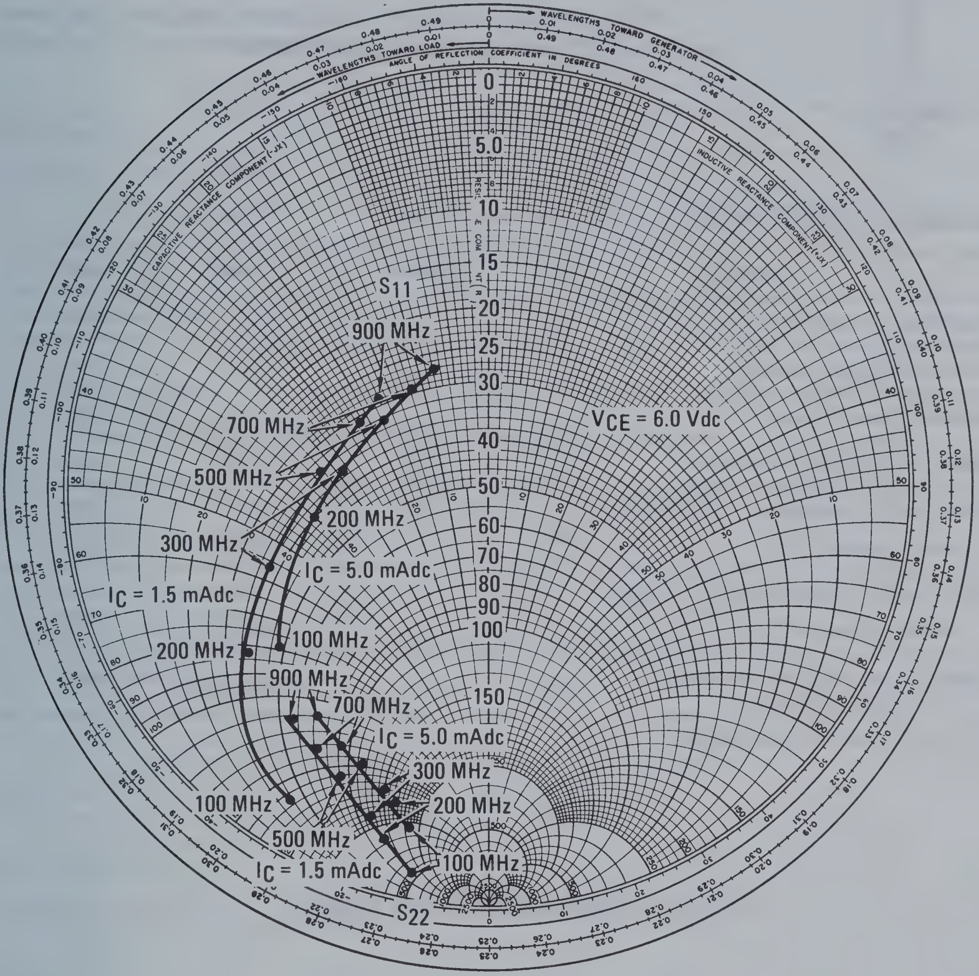
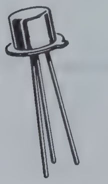


FIGURE 16 – S_{11}, INPUT REFLECTION COEFFICIENT AND S_{22}, OUTPUT REFLECTION COEFFICIENT



2N2894 (SILICON)



CASE 22
(TO-18)

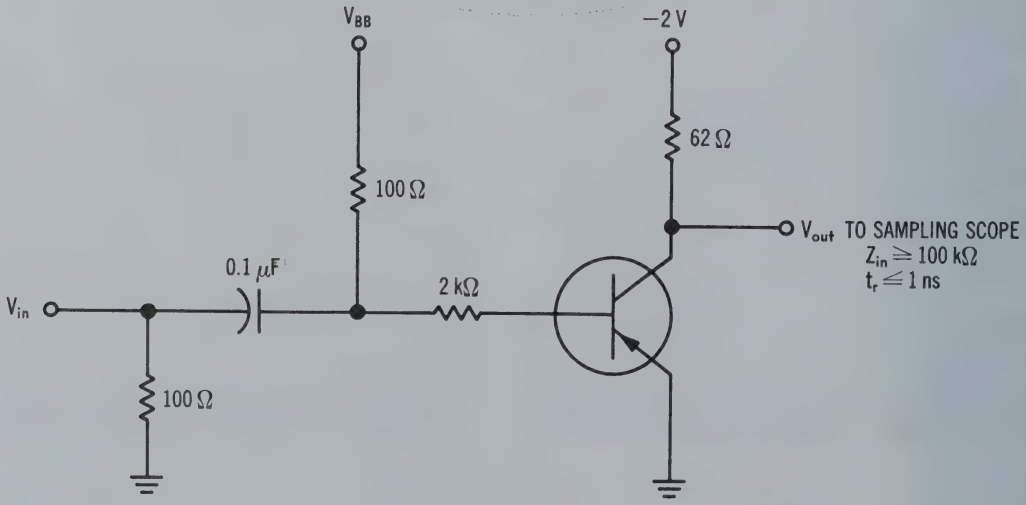
PNP silicon annular transistor designed for low-level, high-speed switching applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage *	V_{CEO}*	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current-Continuous	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.06	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1200 6.85	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Applicable from 0.01 to 10 mAdc.

FIGURE 1 — SWITCHING TIME TEST CIRCUIT

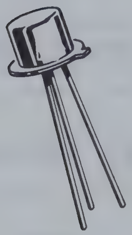

V_{BB}
−2 V
62 Ω
100 Ω
V_{out} TO SAMPLING SCOPE
$Z_{in} \geq 100$ kΩ
$t_r \leq 1$ ns
0.1 μF
2 kΩ
V_{in}
100 Ω

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	12	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	12	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 6 Vdc, V_{BE} = 0)	I_{CES}	—	80	nAdc
Collector-Cutoff Current (V_{CB} = 6 Vdc, I_E = 0, T_A = 125°C)	I_{CBO}	—	10	μAdc
Base Current (V_{CE} = 6 Vdc, V_{BE} = 0)	I_B	—	80	nAdc
ON CHARACTERISTICS				
DC Current Gain (1)	h_{FE}			—
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		30	—	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc)		40	150	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C)		17	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		25	—	
Collector-Emitter Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		—	0.15	
(I_C = 30 mAdc, I_B = 3 mAdc)		—	0.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	0.5	
Base-Emitter Saturation Voltag (1)	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		0.78	0.98	
(I_C = 30 mAdc, I_B = 3 mAdc)		0.85	1.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	1.7	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	6.0	pF
Input Capacitance (V_{BE} = -0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	6.0	pF
Turn-On Time, Figure 1 (V_{CC} = 2 Vdc, $V_{BE(off)}$ = 3 Vdc, I_C = 30 mAdc, I_{B1} = 1.5 mAdc)	t_{on}	—	60	ns
Turn-Off Time, Figure 1 (V_{CC} = 2 Vdc, I_C = 30 mAdc, I_{B1} = I_{B2} = 1.5 mAdc)	t_{off}	—	90	ns

(1) Pulse Test: Pulse Width = 300 μs; Duty Cycle = 1%

2N2895 (SILICON)
2N2896
2N2897



CASE 22
(TO-18)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2895	2N2896	2N2897	Unit
Collector-Emitter Voltage	V_{CEO}	65	90	45	Vdc
Collector-Emitter Voltage	V_{CER}	80	140	60	Vdc
Collector-Base Voltage	V_{CB}	120	140	60	Vdc
Emitter-Base Voltage	V_{EB}	← 7.0 →			Vdc
Collector Current	I_C	← 1.0 →			Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	← 0.5 → ← 2.86 →			Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	← 1.8 → ← 10.3 →			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

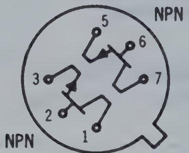
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage [(1)]		$BV_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N2895		65	-	
	2N2896		90	-	
	2N2897		45	-	
Collector-Emitter Breakdown Voltage [(1)]		BV_{CER}			Vdc
(I_C = 100 mAdc, R_{BE} = 10 ohms)	2N2895		80	-	
	2N2896		140	-	
	2N2897		60	-	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 0.1 mAdc, I_E = 0)	2N2895		120	-	
	2N2896		140	-	
	2N2897		60	-	
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 60 Vdc, I_E = 0)	2N2895		-	0.002	
	2N2896		-	0.01	
	2N2897		-	0.05	
(V_{CB} = 60 Vdc, I_E = 0, T_A = +150°C)	2N2895		-	2.0	
	2N2897		-	50	
(V_{CB} = 90 Vdc, I_E = 0)	2N2896		-	0.01	
(V_{CB} = 90 Vdc, I_E = 0, T_A = +150°C)	2N2896		-	10	
Emitter Cutoff Current		I_{EBO}			μAdc
(V_{BE} = 5.0 Vdc, I_C = 0)	2N2895		-	0.002	
	2N2896		-	0.01	
	2N2897		-	0.05	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 10 μAdc, V_{CE} = 10 Vdc)	2N2895		10	-	
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	2N2895		20	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2896, 2N2897		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2895		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2895, 2N2896		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) [(1)]	2N2895		40	120	
	2N2896		60	200	
	2N2897		50	200	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) [(1)]	2N2895		25	-	
Collector-Emitter Saturation Voltage [(1)]		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N2895, 2N2896		-	0.6	
	2N2897		-	1.0	
Base-Emitter Saturation Voltage [(1)]		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N2895, 2N2896		-	1.2	
	2N2897		-	1.3	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N2895, 2N2896		120	-	
	2N2897		100	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	80	pF
Small-Signal Current Gain		h_{fe}			-
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2895		50	200	
	2N2896, 2N2897		50	275	
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 500 ohms, f = 1.0 kHz, BW = 15 kHz)	2N2895	NF	-	8.0	dB

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 1.8%.

2N2903 (SILICON)
2N2903A

Dual NPN silicon transistors designed for differential amplifier applications.

Case 654-04
TO-78



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Power Dissipation @ T_A = 25°C	P_D	200	300	mW
Derate above 25°C		1.14	1.71	mW/°C
Power Dissipation @ T_C = 25°C	P_D	600	1200	mW
T_C = 100°C		350	700	mW
Derate above 25°C		3.43	6.86	mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25 C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 - -	 0.01 15	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	0.01	μAdc

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (each side) (T_A · 25 C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 μAdc, V_{CE} = 5.0 Vdc) (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	h_{FE}	60 25 125 60	- - 625 -	-
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	1.0	-	k ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{re}	-	6.0	$X\ 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	150	600	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	5.0	30	μmhos
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	5.0	$X\ 10^{-4}$
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.2	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz)	NF	-	7.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2903 2N2903A	h_{FE1}/h_{FE2}**	 0.8 0.9	 1.0 1.0	-
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N2903 2N2903A	$\lvert V_{BE1}-V_{BE2}\rvert$	 - -	 10 5.0	mVdc
Base Voltage Differential Gradient (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C) 2N2903 2N2903A	$\dfrac{\Delta\left(V_{BE1}-V_{BE2}\right)}{\Delta T_A}$	 - -	 20 10	μV/°C

** Lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2904,A thru 2N2907,A(SILICON)
2N3485,A, 2N3486,A

PNP SILICON ANNULAR HERMETIC TRANSISTORS

. . . designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry.

- High DC Current Gain Specified – 0.1 to 500 mAdc
- High Current-Gain–Bandwidth Product – f_T = 200 MHz (Min) @ I_C = 50 mAdc
- Low Collector-Emitter Saturation Voltage – $V_{CE(sat)}$ = 0.4 Vdc (Max) @ I_C = 150 mAdc
- 2N2904,A thru 2N2907,A Complement to NPN 2N2218,A, 2N2219,A, 2N2221,A, 2N2222,A
- JAN/JTX Available, Except 2N3485 and 2N3486.

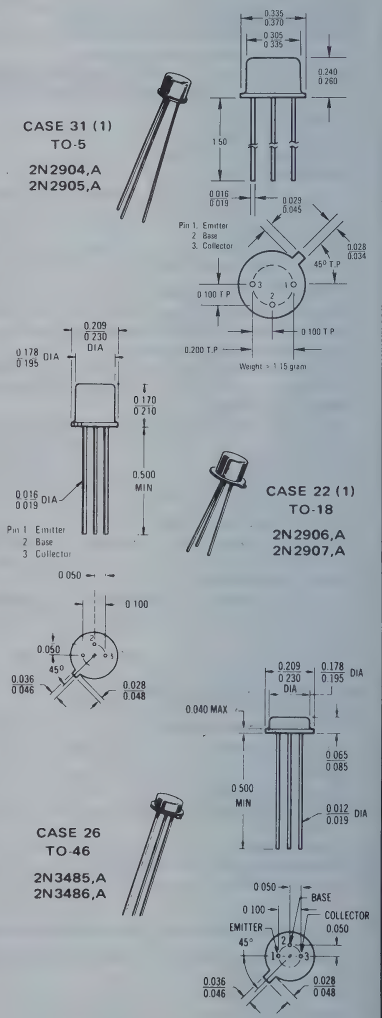
PNP SILICON SWITCHING AND AMPLIFIER TRANSISTORS

SELECTOR GUIDE

<table>
<tr><th rowspan="3">Device Type</th><th colspan="4">Characteristic</th><th rowspan="3">Package</th></tr>
<tr><th>BV_{CEO}</th><th colspan="3">h_{FE}</th></tr>
<tr><th>I_C = 10 mAdc Volts</th><th>I_C = 1.0 mAdc Min</th><th>I_C = 150 mAdc Min</th><th>I_C = 500 mAdc Min</th></tr>
<tr><td>2N2904</td><td>40</td><td>25</td><td>40</td><td>20</td><td rowspan="2">TO-5</td></tr>
<tr><td>2N2905</td><td></td><td>50</td><td>100</td><td>30</td></tr>
<tr><td>2N2906</td><td></td><td>25</td><td>40</td><td>20</td><td rowspan="2">TO-18</td></tr>
<tr><td>2N2907</td><td></td><td>50</td><td>100</td><td>30</td></tr>
<tr><td>2N3485</td><td></td><td>25</td><td>40</td><td>20</td><td rowspan="2">TO-46</td></tr>
<tr><td>2N3486</td><td></td><td>50</td><td>100</td><td>30</td></tr>
<tr><td>2N2904A</td><td>60</td><td>40</td><td>40</td><td>40</td><td rowspan="2">TO-5</td></tr>
<tr><td>2N2905A</td><td></td><td>100</td><td>100</td><td>50</td></tr>
<tr><td>2N2906A</td><td></td><td>40</td><td>40</td><td>40</td><td rowspan="2">TO-18</td></tr>
<tr><td>2N2907A</td><td></td><td>100</td><td>100</td><td>50</td></tr>
<tr><td>2N3485A</td><td></td><td>40</td><td>40</td><td>40</td><td rowspan="2">TO-46</td></tr>
<tr><td>2N3486A</td><td></td><td>100</td><td>100</td><td>50</td></tr>
</table>

*MAXIMUM RATINGS

<table>
<tr><th>Rating</th><th>Symbol</th><th colspan="2">Non-A Suffix</th><th>A-Suffix</th><th>Unit</th></tr>
<tr><td>Collector-Emitter Voltage</td><td>V_{CEO}</td><td colspan="2">40</td><td>60</td><td>Vdc</td></tr>
<tr><td>Collector-Base Voltage</td><td>V_{CB}</td><td colspan="3">60</td><td>Vdc</td></tr>
<tr><td>Emitter-Base Voltage</td><td>V_{EB}</td><td colspan="3">5.0</td><td>Vdc</td></tr>
<tr><td>Collector Current – Continuous</td><td>I_C</td><td colspan="3">600</td><td>mAdc</td></tr>
<tr><td></td><td></td><td>2N2904,A
2N2905,A</td><td>2N2906,A
2N2907,A</td><td>2N3485,A
2N3486,A</td><td></td></tr>
<tr><td>Total Device Dissipation @ T_A = 25°C
Derate above 25°C</td><td>P_D</td><td>600
3.43</td><td>400
2.28</td><td>400
2.28</td><td>mW
mW/°C</td></tr>
<tr><td>Total Device Dissipation @ T_C = 25°C
Derate above 25°C</td><td>P_D</td><td>3.0
17.2</td><td>1.8
10.3</td><td>2.0
11.43</td><td>Watts
mW/°C</td></tr>
<tr><td>Operating and Storage Junction Temperature Range</td><td>T_J, T_{stg}</td><td colspan="3">-65 to +200</td><td>°C</td></tr>
</table>



0.335
0.370
0.305
0.335
0.240
0.260
1.50
0.016
0.019
0.029
0.045
Pin 1. Emitter
2 Base
3. Collector
0.028
0.034
45° T.P
0.100 T.P
0.100 T.P
0.200 T.P
Weight ≈ 1.15 gram
0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
Pin 1 Emitter
2 Base
3 Collector
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
0.209
0.230
DIA
0.178
0.195
DIA
0.040 MAX
0.065
0.085
0.500
MIN
0.012
0.019
DIA
0.050
BASE
0.100
COLLECTOR
EMITTER
0.050
45°
0.036
0.046
0.028
0.048

CASE 31 (1)
TO-5
2N2904,A
2N2905,A

CASE 22 (1)
TO-18
2N2906,A
2N2907,A

CASE 26
TO-46
2N3485,A
2N3486,A

The respective JEDEC registered dimensions and notes apply

***ELECTRICAL CHARACTERISTICS** (T_A = 25° unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage(1) (I_C = 10 mAdc, I_B = 0)	Non-A Suffix	BV_{CEO}	40	–	–	Vdc
	A-Suffix		60	–	–	
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)		BV_{CBO}	60	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	5.0	–	–	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)		I_{CEX}	–	–	50	nAdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	Non-A Suffix	I_{CBO}	–	–	0.020	µAdc
	A-Suffix		–	–	0.010	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	Non-A Suffix		–	–	20	
	A-Suffix		–	–	10	
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)		I_B	–	–	50	nAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485	h_{FE}	20	–	–	–
	2N2905,2N2907,2N3486		35	–	–	
	2N2904A,2N2906A,2N3485A		40	–	–	
	2N2905A,2N2907A,2N3486A		75	–	–	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485		25	–	–	
	2N2905,2N2907,2N3486		50	–	–	
	2N2904A,2N2906A,2N3485A		40	–	–	
	2N2905A,2N2907A,2N3486A		100	–	–	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485		35	–	–	
	2N2905,2N2907,2N3486		75	–	–	
	2N2904A,2N2906A,2N3485A		40	–	–	
	2N2905A,2N2907A,2N3486A		100	–	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)(1)	2N2904,A,2N2906,A,2N3485,A		40	–	120	
	2N2905,A,2N2907,A,2N3486,A		100	–	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)(1)	2N2904,2N2906,2N3485		20	–	–	
	2N2905,2N2907,2N3486		30	–	–	
	2N2904A,2N2906A,2N3485A		40	–	–	
	2N2905A,2N2907A,2N3486A		50	–	–	
Collector-Emitter Saturation Voltage(1) (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	–	–	0.4	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			–	–	1.6	
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)(1)		$V_{BE(sat)}$	–	–	1.3	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			–	–	2.6	
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product(2) (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	200	–	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	–	–	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	–	–	30	pF
SWITCHING CHARACTERISTICS						
Turn-On Time	(V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 15a)	t_{on}	–	26	45	ns
Delay Time		t_d	–	6.0	10	ns
Rise Time		t_r	–	20	40	ns
Turn-Off Time	(V_{CC} = 6.0 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc) (Figure 15b)	t_{off}	–	70	100	ns
Storage Time		t_s	–	50	80	ns
Fall Time		t_f	–	20	30	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

FIGURE 1 – NORMALIZED DC CURRENT GAIN

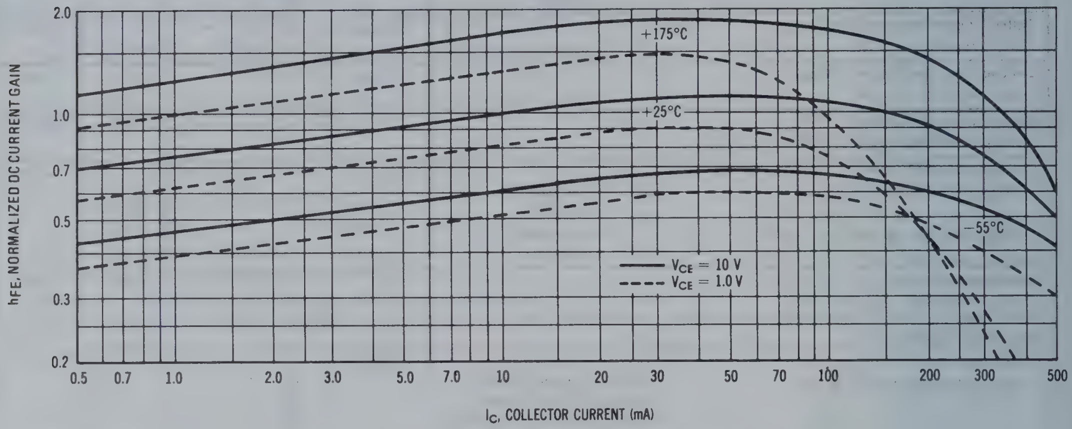
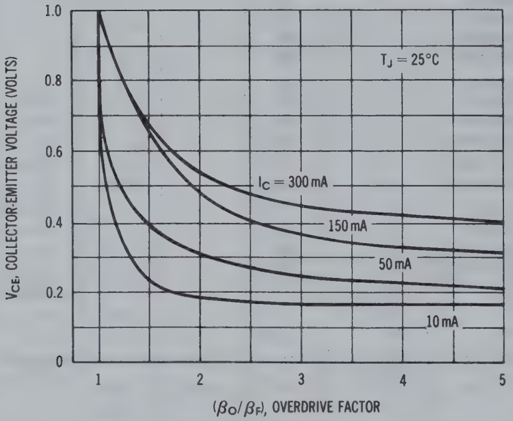


FIGURE 2 – NORMALIZED COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_O (current gain at edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

EXAMPLE: For type 2N2905, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at $I_C = 150$ mA an overdrive factor of at least 3 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is approximately 0.60 of h_{FE} @ 10 volts. Using the guaranteed minimum of 100 @ 150 mA and 10 V, $\beta_O = 60$ and substituting values in the overdrive equation, we find:

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\ V}{I_C/I_{BF}} \qquad 3 = \frac{60}{150/I_{BF}} \qquad I_{BF} \approx 7.5\ mA$$

FIGURE 3 – "ON" VOLTAGES

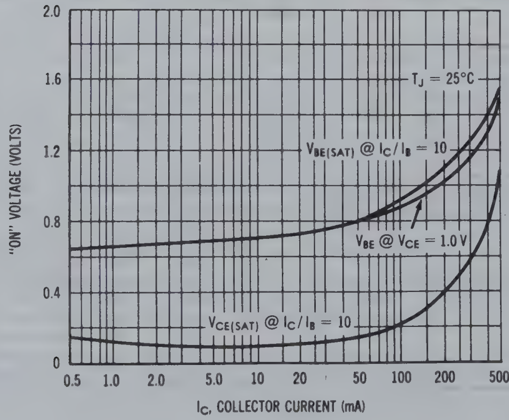
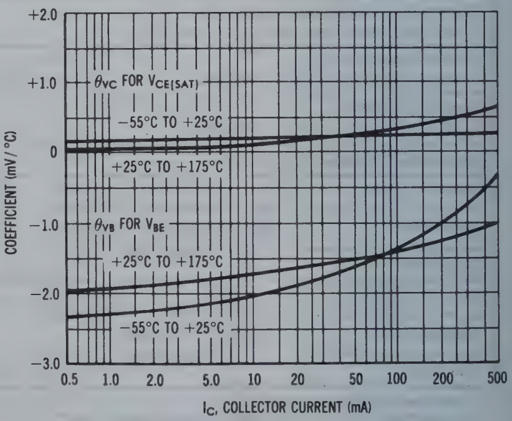


FIGURE 4 – TEMPERATURE COEFFICIENTS



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 10 V, T_A = 25°C

FIGURE 5 – FREQUENCY EFFECTS

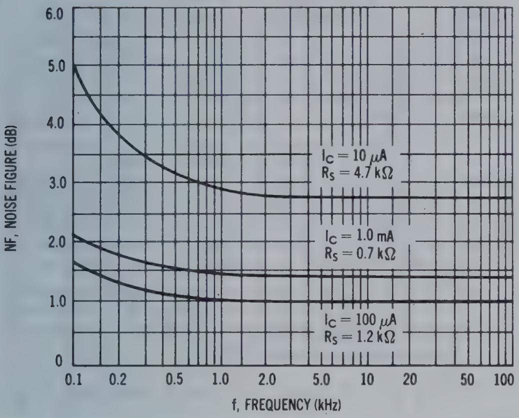
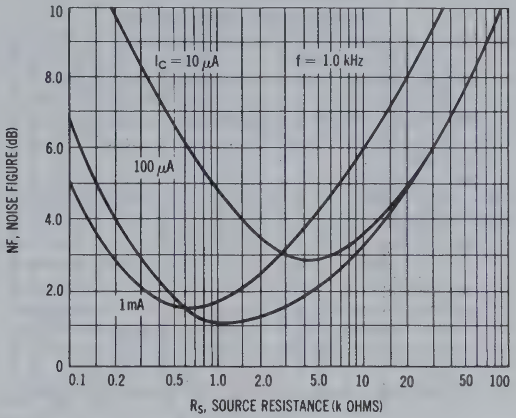


FIGURE 6 – SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 7 – INPUT IMPEDANCE

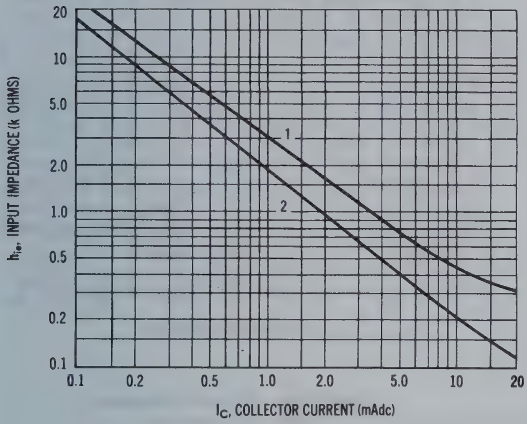


FIGURE 8 – VOLTAGE FEEDBACK RATIO

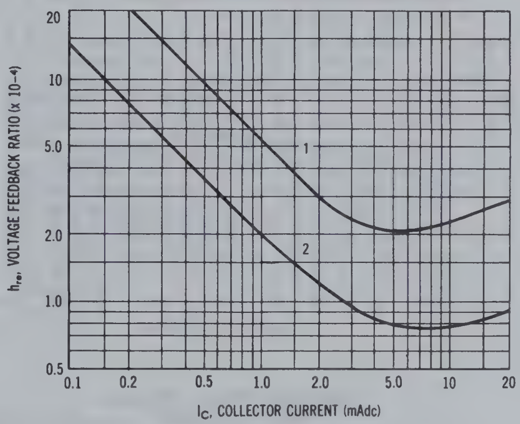


FIGURE 9 – CURRENT GAIN

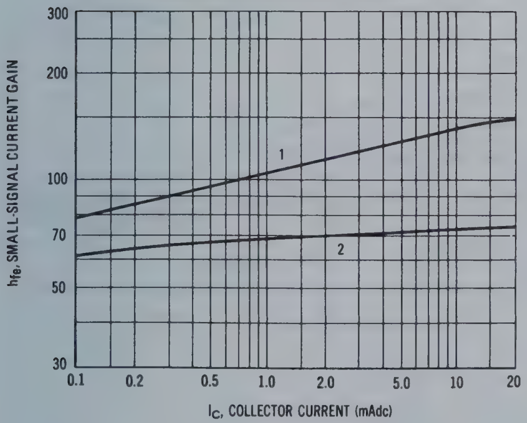


FIGURE 10 – OUTPUT ADMITTANCE

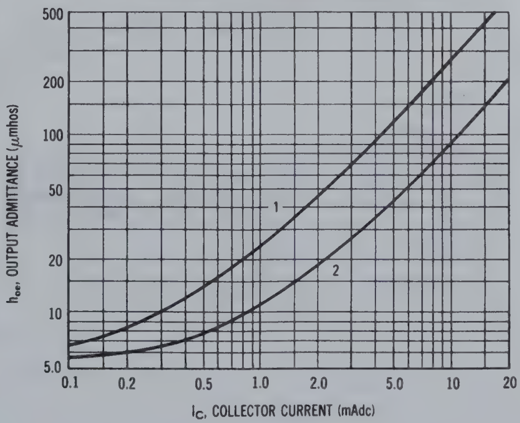


FIGURE 11 – TURN ON TIME

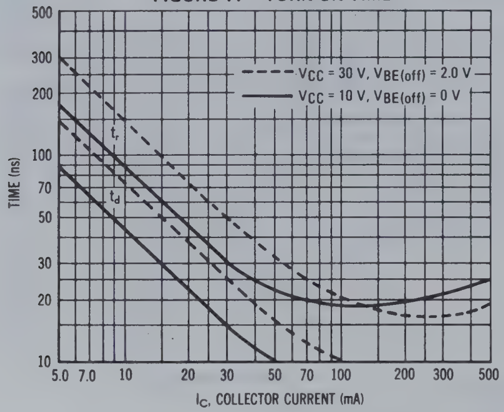


FIGURE 12 – CHARGE DATA

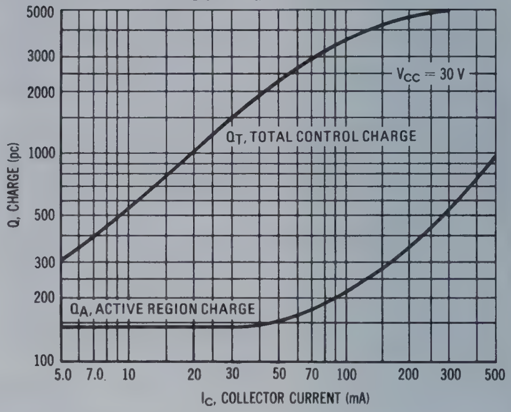


FIGURE 13 – STORAGE TIME

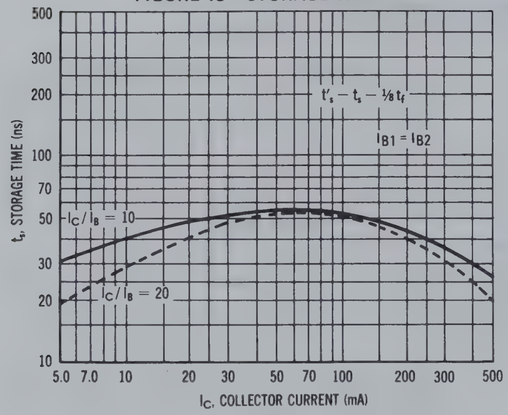


FIGURE 14 – FALL TIME

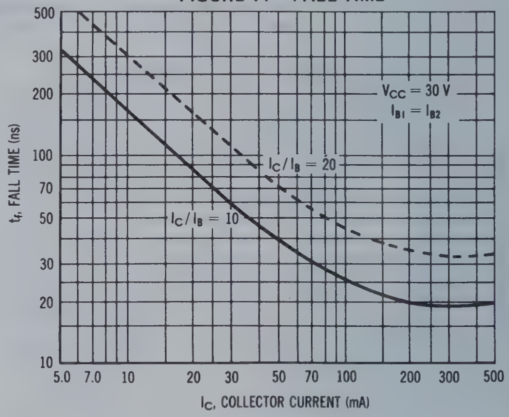


FIGURE 15a – DELAY AND RISE TIME TEST CIRCUIT

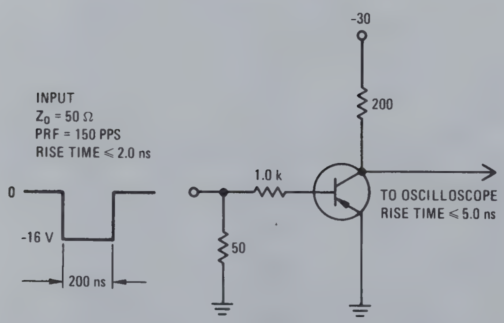

INPUT
Z0 = 50 Ω
PRF = 150 PPS
RISE TIME ≤ 2.0 ns
0
-16 V
200 ns
-30
200
1.0 k
50
TO OSCILLOSCOPE
RISE TIME ≤ 5.0 ns

FIGURE 15b – STORAGE AND FALL TIME TEST CIRCUIT

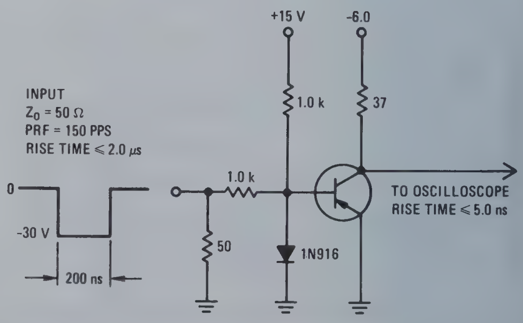

INPUT
Z0 = 50 Ω
PRF = 150 PPS
RISE TIME ≤ 2.0 µs
0
-30 V
200 ns
+15 V
-6.0
1.0 k
37
1.0 k
50
1N916
TO OSCILLOSCOPE
RISE TIME ≤ 5.0 ns

FIGURE 16 – CURRENT-GAIN–BANDWIDTH PRODUCT

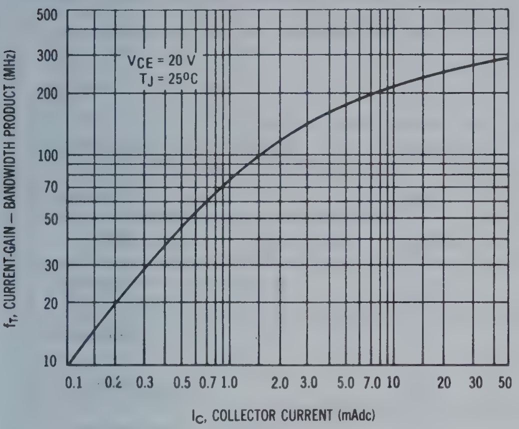


FIGURE 17 – CAPACITANCES

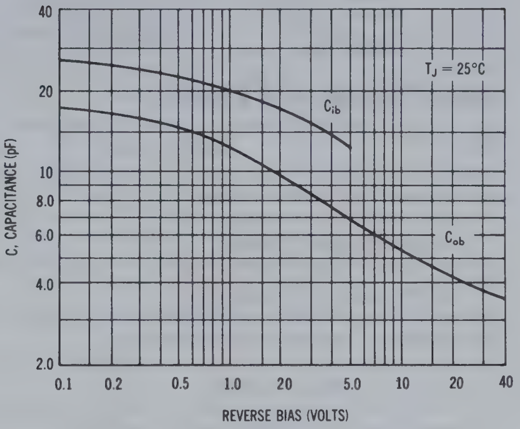
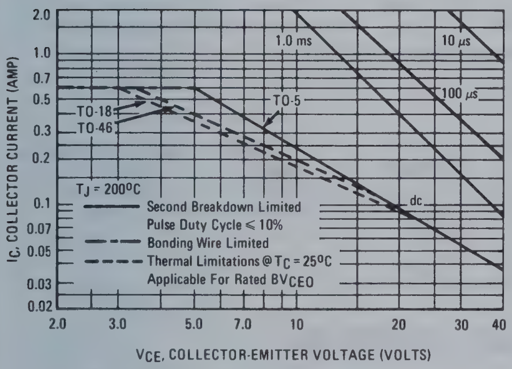


FIGURE 18 – ACTIVE REGION SAFE OPERATING AREAS

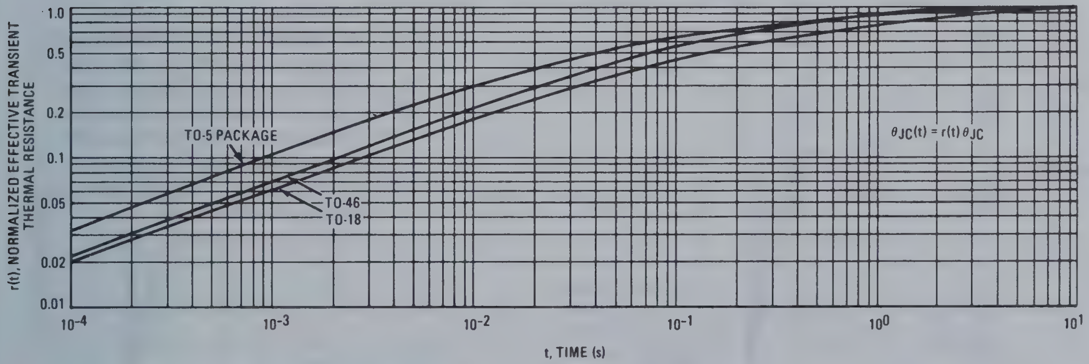


This graph shows the maximum I_C-V_{CE} limits of the device both from the standpoint of thermal dissipation (at 25°C case temperature), and secondary breakdown. For case temperatures other than 25°C, the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

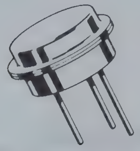
To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

For pulse applications, the maximum I_C-V_{CE} product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

FIGURE 19 – THERMAL RESPONSE



2N2912 (GERMANIUM)



CASE 8

PNP high-speed, high-frequency power transistor especially designed for switching and power converter circuits operating from low-voltage power sources such as solar cells, thermo-electric generators, sea cells, fuel cells and 1.5 volt batteries.

MAXIMUM RATINGS

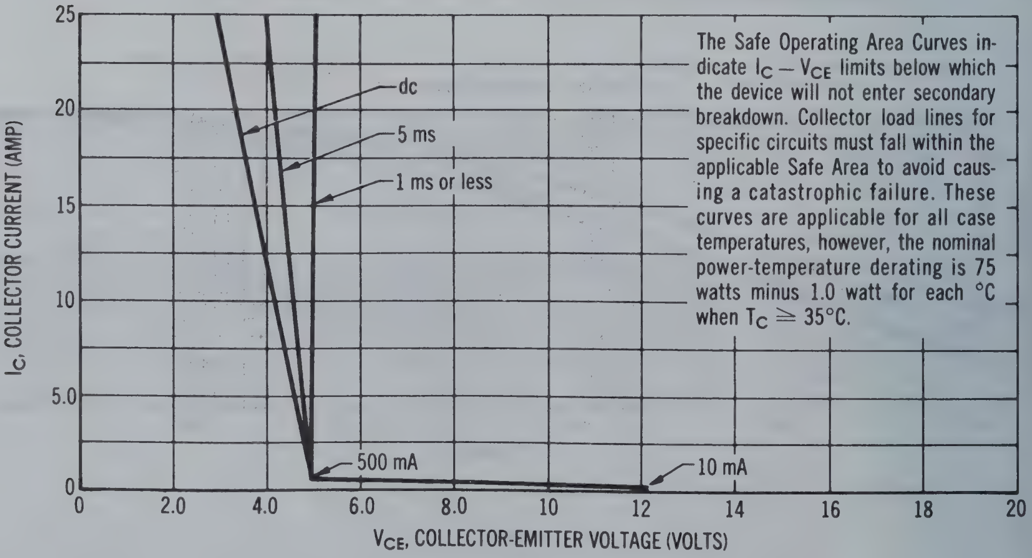
Rating	Symbol	Rating	Unit
Collector-Emitter Voltage	V_{CEO}	5.0	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	1.5	Vdc
Collector Current-Continuous	I_C	25	Adc
Base Current-Continuous	I_B	3.0	Adc
Total Device Dissipation @ T_C = 35°C Derate above 35°C	P_D	75 1.0	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

Lead temperature 1/16″ from case for 10 seconds = 240°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	30	°C/W

FIGURE 1 — ACTIVE-REGION SAFE OPERATING AREA



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. These curves are applicable for all case temperatures, however, the nominal power-temperature derating is 75 watts minus 1.0 watt for each °C when $T_C \geqq 35°C$.

2N2912 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 500 mAdc, I_B = 0)		BV_{CEO}*	5.0	—	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 500 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)		I_{CES}	—	10	mAdc
Collector Cutoff Current (V_{CE} = 15 Vdc, R_{BE} = 5.0 ohms)		I_{CER}	—	10	mAdc
Collector Cutoff Current (V_{CE} = 15 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 5.0 Vdc, $V_{EB(off)}$ = 0.2 Vdc, T_C = 85°C)		I_{CEX}	— —	10 15	mAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)		I_{CBO}	—	10	mAdc
Emitter Cutoff Current (V_{BE} = 1.5 Vdc, I_C = 0)		I_{EBO}	—	50	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 Adc, V_{CE} = 2.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2	h_{FE}	150 200	— 800	—
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc) (I_C = 25 Adc, I_B = 2.5 Adc)	2	$V_{CE(sat)}$	— —	0.12 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc) (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{BE(sat)}$	— —	0.5 1.2	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc, f = 1.0 MHz)		f_T	10	—	MHz
Rise Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_r	—	2.0	µs
Storage Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_s	—	10	µs
Fall Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_f	—	2.0	µs

*Sweep Test: 1/2 Cycle sine wave, 60 Hz

FIGURE 2 — TYPICAL COLLECTOR CHARACTERISTICS

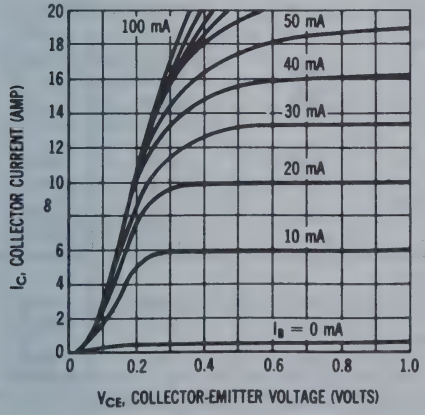
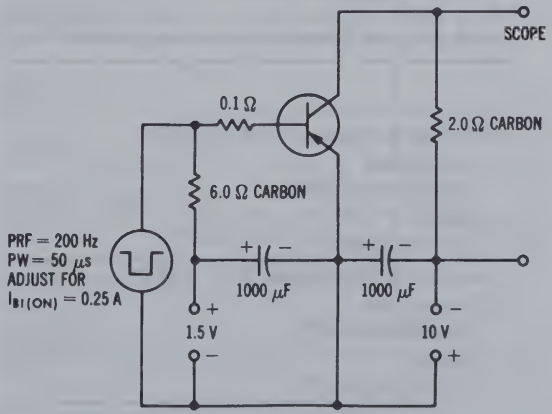


FIGURE 3 — SWITCHING-TIME TEST CIRCUIT



2N2913 thru 2N2920 (SILICON)

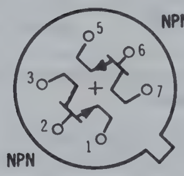
2N2972 thru 2N2979
2N2919 JAN & JTX
2N2920 JAN & JTX AVAILABLE

Dual NPN silicon annular transistors, especially designed for low-level, low-noise differential-amplifier applications, feature very high Beta guaranteed from 10 μAdc to 1.0 mAdc and excellent noise characteristics.

CASE 635
(TO-71)

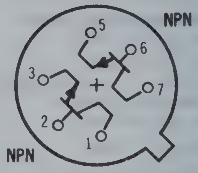
CASE 654-04

2N2972
thru
2N2979



Pins 4 and 8 omitted

2N2913
thru
2N2920



Pin Connections, Bottom View
All Leads Electrically Isolated From Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N2913–18 2N2972–77	2N2919–20 2N2978–79	Unit
Collector-Emitter Voltage	V_{CEO}	45	60	Vdc
Collector-Base Voltage	V_{CB}	45	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
Case 654-04		300	600	mW
Derate above 25°C		1.7	3.4	mW/°C
Case 655		250	300	mW
Derate above 25°C		1.43	1.72	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			
Case 654-04		750	1500	mW
Derate above 25°C		4.3	8.6	mW/°C
Case 655		500	750	mW
Derate above 25°C		2.85	4.3	mW/°C

2N2913 thru 2N2920, 2N2972 thru 2N2979 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	2N2913 thru 18, 2N2972 thru 77	$BV_{CEO(sus)}$	45		-	Vdc
	2N2919, 2N2920, 2N2978, 2N2979		60		-	
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	2N2913 thru 18, 2N2972 thru 77	BV_{CBO}	45		-	Vdc
	2N2919, 2N2920, 2N2978, 2N2979		60		-	
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	6.0		-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)		I_{CEO}	-	-	0.002	µAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)	2N2913 thru 18, 2N2972 thru 77	I_{CBO}	-	-	0.010	µAdc
	2N2919, 2N2920, 2N2978, 2N2979		-	-	0.002	
(V_{CB} = 45 Vdc, I_E = 0, T_A = 150°C)	All Types		-	-	10	
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	-	0.002	µAdc
ON CHARACTERISTICS						
DC Current Gain (1) (I_C = 10 µAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78	h_{FE}	60	-	240	-
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		150	-	600	
(I_C = 10 µAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		15	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		30	-	-	
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		100	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		225	-	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		150	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		300	-	-	
Collector-Emitter Saturation Voltage (I_C = 1.0 mAdc, I_B = 0.1 mAdc)		$V_{CE(sat)}$	-	-	0.35	Vdc
Base-Emitter On Voltage (I_C = 100 µAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	-	-	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 500 µAdc, V_{CE} = 5.0 Vdc, f = 20 MHz)		f_T	60	-	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	-	4.0	6.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	25	28	32	ohms
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	-	1.0	µmhos
Noise Figure (I_C = 10 µAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz, BW = 200 Hz)	2N2914, 16, 18, 20, 2N2973, 75, 77, 79	NF	-	2.0	3.0	dB
	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		-	3.0	4.0	
(I_C = 10 µAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz, BW = 10 kHz)	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		- -	2.0	3.0	
	2N2913, 15, 17, 19, 2N2972, 74, 76, 78			3.0	4.0	
DC Current Gain Ratio** (I_C = 100 µAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77	h_{FE1}/h_{FE2}**	0.8	-	1.0	-
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		0.9	-	1.0	
Base Voltage Differential (I_C = 10 µAdc to 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77	$\lvert V_{BE1}-V_{BE2}\rvert$	-	-	10	mVdc
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	5.0	
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77		-	-	5.0	
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	3.0	
Base Voltage Differential Gradient (I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +25°C)	2N2917, 18, 2N2976, 77	$\Delta(V_{BE1}-V_{BE2})$	-	-	1.6	mVdc
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	0.8	
(I_C = 100 µAdc, V_{CE} = 5.0 Vdc, T_A = +25°C to +125°C)	2N2917, 18, 2N2976, 77		-	-	2.0	
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	1.0	

(1) Pulse Test: Pulse Width ≦ 300 µs, Duty Cycle ≦ 2.0%.

** The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

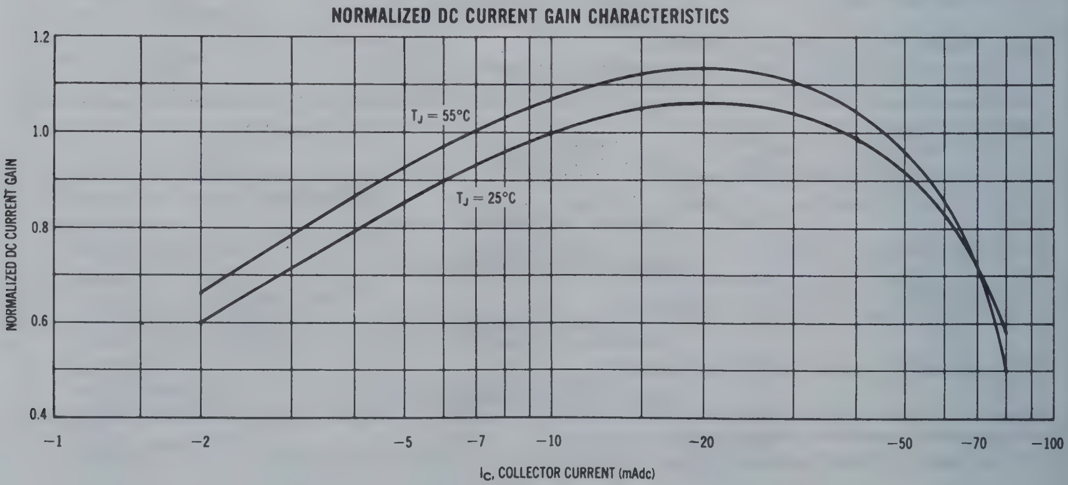
2N2929 (GERMANIUM)

CASE 31
(TO-5)
Collector connected to case

PNP germanium epitaxial mesa transistor for low noise, broadband, power and driver amplifier applications.

MAXIMUM RATINGS

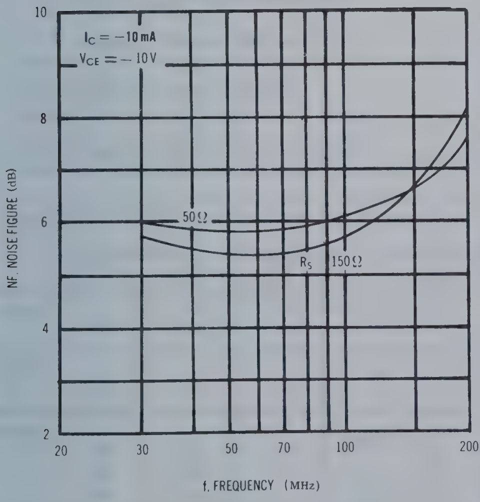
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	10	Vdc
Emitter-Base Voltage	V_{EB}	0.75	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 4.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	750 10	mW mW/°C
Junction Temperature	T_J	100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C



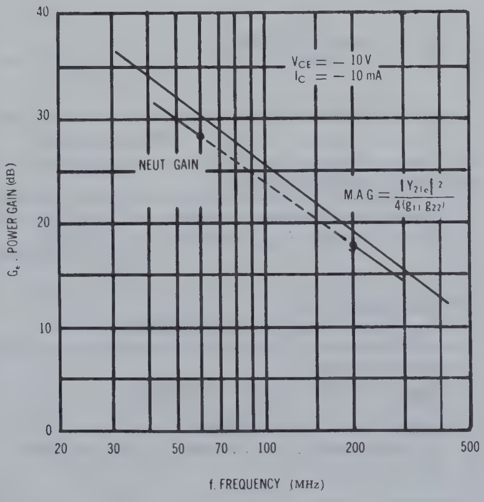
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Sym	Test Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 μAdc, I_E = 0	25	45	—	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 100 μAdc, V_{EB} = 0	25	45	—	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 10 mAdc, I_B = 0	10	20	—	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 1 mAdc, I_C = 0	0.75	1.5	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0 V_{CB} = 10 Vdc, I_E = 0, T_A = +55°C	— —	0.15 —	5.0 50	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	—	1.0	100	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 10 mAdc	10	30	100	—
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 50 mAdc, I_B = 10 mAdc	—	0.15	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 50 mAdc, I_B = 10 mAdc	—	0.55	1.0	Vdc
Small-Signal Forward Current Transfer Ratio	h_{fe}	I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz	10	35	120	—
Current Gain - Bandwidth Product	f_T	I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz I_C = 40 mAdc, V_{CE} = 10 Vdc, f = 100 MHz	800 1000 700	1100 1250 1200	1400 1600 —	MHz
Collector-Base Time Constant	$r_b' C_c$	V_{CB} = 10 Vdc, I_E = 20 mAdc, f = 31.8 MHz	10	25	40	ps
Real Part of Small-Signal Short Circuit Input Impedance	$Re(h_{ie})$	I_C = 10 mA, V_{CE} = 10 V, f = 1000 MHz	—	45	75	ohms
Collector-Base Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	—	1.75	2.5	pF
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 10 mAdc, f = 60 MHz V_{CE} = 10 Vdc, I_C = 10 mAdc, f = 200 MHz	26 —	28 16	— —	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 Adc, f = 200 MHz R_G = 50 Ω	—	5.5	—	dB

NOISE FIGURE versus FREQUENCY



MAXIMUM AVAILABLE GAIN versus FREQUENCY



2N2944 (SILICON)
2N2945
2N2946

PNP silicon annular transistors designed for low-level, high-speed chopper applications.

CASE 26
(TO-46)
Collector electrically connected to case

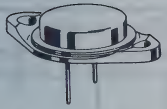
MAXIMUM RATINGS

Rating	Symbol	2N2944	2N2945	2N2946	Unit
Emitter-Collector Voltage	V_{ECO}	10	20	35	Vdc
Collector-Base Voltage	V_{CB}	15	25	40	Vdc
Emitter-Base Voltage	V_{EB}	15	25	40	Vdc
Collector Current	I_C	← 100 →			mAdc
Total Device Dissipation @ $T_A = 25°C$	P_D	← 500 →			mW
Derate above 25°C		← 2.8 →			mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	← 2.0 →			Watts
Derate above 25°C		← 11.4 →			mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector Cutoff Current		I_{CBO}				nAdc
($V_{CB} = 15$ Vdc, $I_E = 0$)	2N2944		-	-	0.1	
($V_{CB} = 25$ Vdc, $I_E = 0$)	2N2945		-	-	0.2	
($V_{CB} = 40$ Vdc, $I_E = 0$)	2N2946		-	-	0.5	
Emitter Cutoff Current		I_{EBO}				nAdc
($V_{EB} = 15$ Vdc, $I_C = 0$)	2N2944		-	-	0.1	
($V_{EB} = 25$ Vdc, $I_C = 0$)	2N2945		-	-	0.2	
($V_{EB} = 40$ Vdc, $I_C = 0$)	2N2946		-	-	0.5	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
($I_C = 1.0$ mAdc, $V_{CE} = 0.5$ Vdc)	2N2944		80	180	-	
	2N2945		40	160	-	
	2N2946		30	130	-	
Forward Current Transfer Ratio (inverted connection)		$h_{FE(inv)}$				-
($I_C = 200$ μAdc, $V_{CE} = 0.5$ Vdc)	2N2944		6.0	20	-	
	2N2945		4.0	17	-	
	2N2946		3.0	15	-	
Offset Voltage		$V_{EC(off)}$				mVdc
($I_B = 200$ μAdc, $I_E = 0$)	2N2944		-	0.18	0.3	
	2N2945		-	0.23	0.5	
	2N2946		-	0.27	0.8	
($I_B = 1.0$ mAdc, $I_E = 0$)	2N2944		-	0.4	0.6	
	2N2945		-	0.5	1.0	
	2N2946		-	0.6	2.0	
($I_B = 2.0$ mAdc, $I_E = 0$)	2N2944		-	0.8	1.0	
	2N2945		-	0.9	1.6	
	2N2946		-	1.0	2.5	
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product		f_T				MHz
($I_C = 1.0$ mAdc, $V_{CE} = 6.0$ Vdc, f = 1.0 MHz)	2N2944		10	15	-	
	2N2945		5.0	13	-	
	2N2946		3.0	12	-	
Output Capacitance ($V_{CB} = 6.0$ Vdc, $I_E = 0$, f = 500 kHz)		C_{ob}	-	3.2	10	pF
Input Capacitance ($V_{EB} = 6.0$ Vdc, $I_C = 0$, f = 500 kHz)		C_{ib}	-	1.9	6.0	pF
Dynamic On Series Resistance		$r_{ec(on)}$				Ohms
($I_C = 100$ μAdc, $I_B = 1.0$ mAdc, $I_E = 0$, f = 1.0 kHz)	2N2944		-	4.0	20	
	2N2945		-	4.5	35	
	2N2946		-	5.0	45	

2N2947 (SILICON)
2N2948



CASE 1
(TO-3)

Collector connected to case

NPN silicon annular transistors for power amplifier applications to 100 MHz.

MAXIMUM RATINGS*

Rating	Symbol	2N2947	2N2948	Unit
Collector-Base Voltage	V_{CB}	60	40	Vdc
Collector-Emitter Voltage	V_{CES}	60	40	Vdc
Emitter - Base Voltage	V_{EB}	3.0	2.0	Vdc
Collector-Current (continuous)	I_C	1.5		Adc
Base-Current (continuous)	I_B	500		mAdc
Power Input (Nominal)	P_{in}	5.0		Watts
Power Output (Nominal)	P_{out}	20.0		Watts
Total Device Dissipation @ 25°C Case Temperature	P_D	25.0		Watts
Derating Factor above 25°C		167		mW/°C
Junction Temperature	T_J	175		°C
Storage Temperature Range	T_{stg}	-65 to + 175		°C

*The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See electrical characteristics.

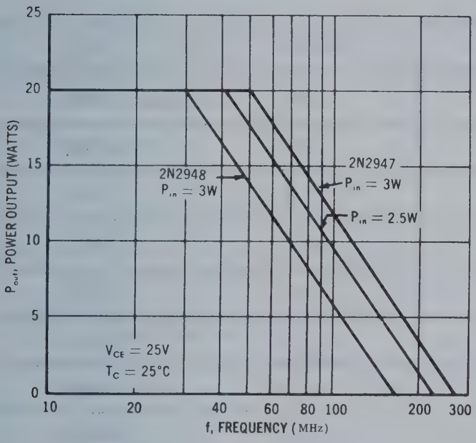
2N2947, 2N2948 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

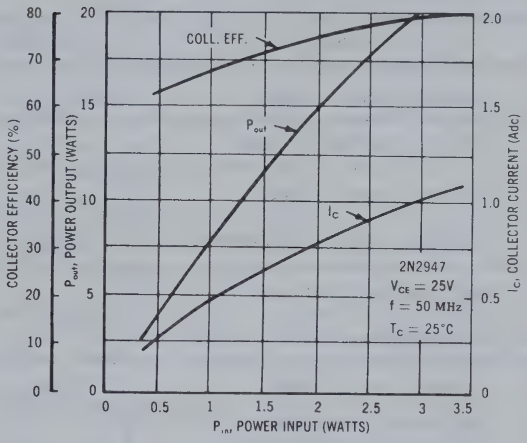
Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES\ (sus)}$ (1)	2N2947: I_C = 0.250 A, R_{BE} = 0	90	120	--	Volts
		2N2948: I_C = 0.250A, R_{BE} = 0	80	100	--	
Collector-Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$ (1)	2N2947: I_C = 0.250A, I_B = 0	40	--	--	Volts
		2N2948: I_C = 0.250A, I_B = 0	20	--	--	
Collector-Emitter Current	I_{CES}	2N2947: V_{CE} = 60 Vdc, V_{BE} = 0	--	--	0.5	mAdc
		V_{CE} = 50 Vdc, V_{BE} = 0, T_C = 175°C	--	--	1.0	
		2N2948: V_{CE} = 40 Vdc, V_{BE} = 0	--	--	0.5	
		V_{CE} = 30 Vdc, V_{BE} = 0, T_C = 175°C	--	--	1.0	
Collector Cutoff Current	I_{CBO}	2N2947: V_{CB} = 50 Vdc, I_E = 0	--	--	1.0	μAdc
		2N2948: V_{CB} = 30 Vdc, I_E = 0	--	--	1.0	
Emitter Cutoff Current	I_{EBO}	2N2947: V_{EB} = 3 Vdc, I_C = 0	--	--	100	μAdc
		2N2948: V_{EB} = 2 Vdc, I_C = 0	--	--	100	
DC Current Gain	h_{FE}	2N2947: I_C = 400 mAdc, V_{CE} = 2Vdc	6.0	--	60	
		2N2948: I_C = 400 mAdc, V_{CE} = 2 Vdc	2.5	--	100	
		Both Types: I_C = 1 Adc, V_{CE} = 2 Vdc	2.5	--	--	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 1.0 Adc, I_B = 500 mAdc	--	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 1.0 Adc, I_B = 500 mAdc	--	--	2.0	Vdc
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 2.0 Vdc, I_C = 400 mAdc, f = 50 MHz	2.0	--	--	
Collector Output Capacitance	C_{ob}	V_{CB} = 25 Vdc, I_E=0, f = 100 kHz	--	--	60	pF
Power Input	P_{in}	P_{out} = 15 W, f = 50 MHz, V_{CE} = 25 Vdc	--	2.0	3.0	Watts
Efficiency	η	$I_{C(max)}$ = 1A 2N2947	60	80	--	%
Power Input	P_{in}	P_{out} = 15 W, f = 30 MHz, V_{CE} = 25 Vdc	--	2.0	3.0	Watts
Efficiency	η	$I_{C(max)}$ = 1.0 A 2N2948	60	70	--	%

(1) Pulse Measurement: Pulse Width ≦ 100 μs, Duty Cycle = 2.0%.

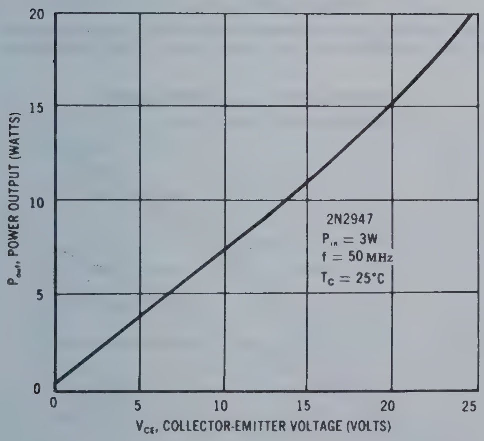
POWER OUTPUT versus FREQUENCY



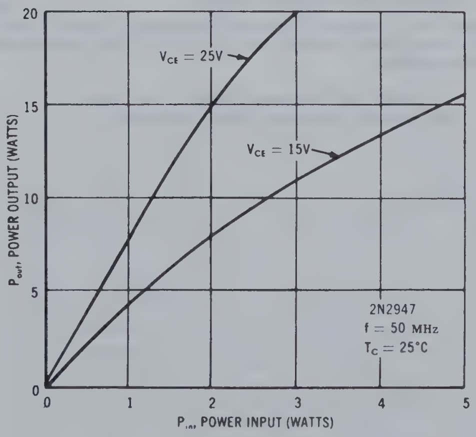
OUTPUT CHARACTERISTICS versus POWER INPUT



POWER OUTPUT versus COLLECTOR VOLTAGE

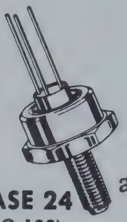


POWER OUTPUT versus POWER INPUT



2N2949 (SILICON)
2N2950

CASE 23
(TO-107)
2N2949



CASE 24
(TO-102)
2N2950

NPN silicon annular transistors for power amplifier and driver applications to 100 MHz.

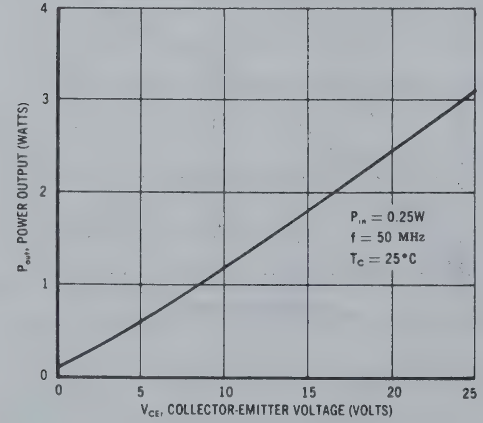
Collector connected to case;
stud isolated from case

MAXIMUM RATINGS*

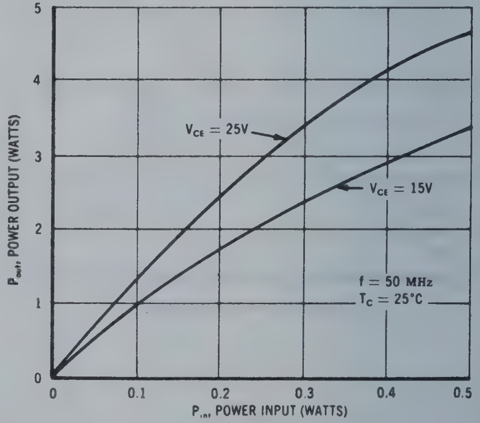
<table>
<tr><th>Rating</th><th>Symbol</th><th colspan="2">Value</th><th>Unit</th></tr>
<tr><td>Collector-Base Voltage</td><td>V_{CB}</td><td colspan="2">60</td><td>Vdc</td></tr>
<tr><td>Collector-Emitter Voltage</td><td>V_{CES}</td><td colspan="2">60</td><td>Vdc</td></tr>
<tr><td>Emitter - Base Voltage</td><td>V_{EB}</td><td colspan="2">3.0</td><td>Vdc</td></tr>
<tr><td>Collector Current (Continuous)</td><td>I_C</td><td colspan="2">0.7</td><td>Adc</td></tr>
<tr><td>Base Current (Continuous)</td><td>I_B</td><td colspan="2">100</td><td>mAdc</td></tr>
<tr><td>RF Input Power (Nom)</td><td>P_{in}</td><td colspan="2">1.0</td><td>Watt</td></tr>
<tr><td>RF Output Power (Nom)</td><td>P_{out}</td><td colspan="2">5.0</td><td>Watts</td></tr>
<tr><td>Total Device Dissipation
(25°C Case temperature)
(Derating Factor above 25°C)</td><td>P_D</td><td colspan="2">6.0
40</td><td>Watts
mW/°C</td></tr>
<tr><td rowspan="2">Total Device Dissipation at
25° Ambient
(Derating Factor above 25°C)</td><td rowspan="2">P_D</td><td>2N2949</td><td>2N2950</td><td rowspan="2">Watt
mW/°C</td></tr>
<tr><td>0.5
3.33</td><td>0.7
4.67</td></tr>
<tr><td>Junction Temperature</td><td>T_J</td><td colspan="2">175</td><td>°C</td></tr>
<tr><td>Storage Temperature Range</td><td>T_{stg}</td><td colspan="2">-65 to + 175</td><td>°C</td></tr>
</table>

* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.

POWER OUTPUT versus COLLECTOR VOLTAGE



POWER OUTPUT versus POWER INPUT

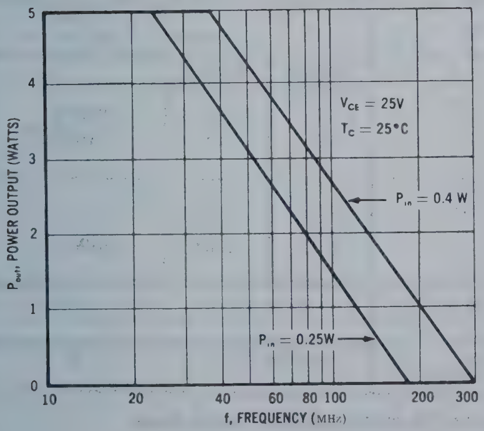


ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

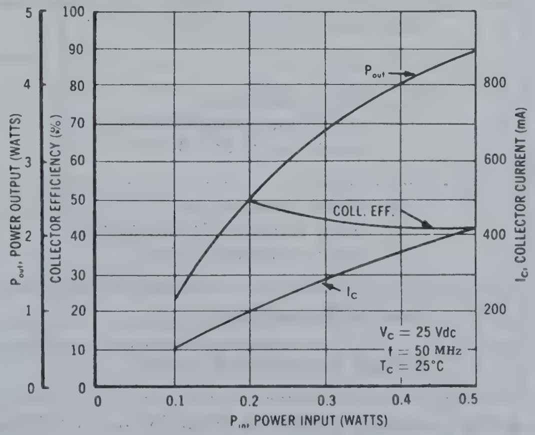
Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$ (1)	I_C=0.250 A, R_{BE}= 0	85	120	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$ (1)	I_C=0.250A, I_B=0	40	--	--	Volts
Collector-Emitter Current	I_{CES}	V_{CE}= 60 Vdc, V_{BE}=0	--	--	100	μAdc
		V_{CE}=50 Vdc, V_{BE}= 0 T_C= + 175°C	--	--	500	
Collector - Cutoff Current	I_{CBO}	V_{CB}=50 Vdc, I_E=0	--	--	0.1	μAdc
Emitter-Cutoff Current	I_{EBO}	V_{EB}= 3 Vdc, I_C=0	--	--	100	μAdc
DC Current Gain	h_{FE}	V_{CE}= 2.0 Vdc I_C= 40 mAdc	5.0	--	100	--
		V_{CE}=2.0 Vdc I_C= 400 mAdc	5.0	--	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C= 400 mAdc, I_B= 80 mAdc	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	I_C=400 mAdc, I_B=80mAdc	--	--	2.0	Vdc
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE}=2.0 Vdc I_C=40 mAdc, f=50 MHz	2.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB}= 25 Vdc, I_E=0 f=100 kHz	--	--	20	pF
Power Input	P_{in}	P_{out}=3.5 watts, f=50 MHz V_{CE}=25 Vdc, $I_{C(max)}$=325 mA	--	--	0.35	Watt
Efficiency	η		43	--	--	%

(1) Pulse Width ≤ 100 μs, Duty Cycle = 2%

POWER OUTPUT versus FREQUENCY

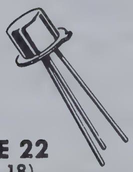


OUTPUT CHARACTERISTICS versus POWER INPUT



2N2951 (SILICON)
2N2952

CASE 31
(TO-5)
2N2951



CASE 22
(TO-18)
2N2952

Collector connected to case

NPN silicon annular Star transistors for power amplifier applications to 100 MHz.

MAXIMUM RATINGS*

Rating	Symbol	Value		Units
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CES}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current (continuous)	I_C	250		mAdc
Base Current (continuous)	I_B	50		mAdc
		2N2951	2N2952	
Total Device Dissipation (25°C Case Temperature) (Derate above 25°C)	P_D	3.0 20	1.8 12	Watts mW/°C
Total Device Dissipation (25°C Ambient Temperature) (Derate above 25°C)	P_D	0.8 5.33	0.5 3.33	mW/°C
Junction Temperature	T_J	-65 to 175		°C
Storage Temperature Range	T_{stg}	-65 to 175		°C

* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.

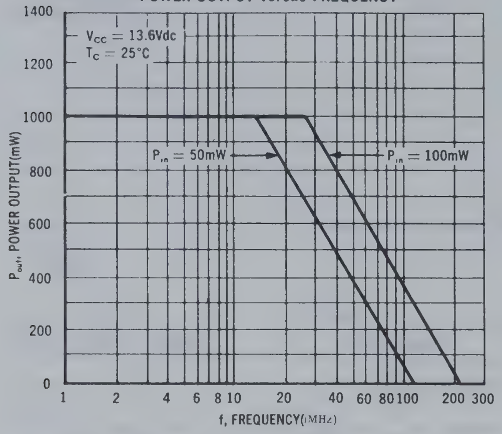
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Max	Unit
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0	--	100	μAdc
		V_{CE} = 50Vdc, V_{BE} = 0, T_C = 175°C	--	500	μAdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 50 Vdc, I_E = 0	--	0.1	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 5 Vdc, I_C = 0	--	100	μAdc
DC Current Gain	h_{FE}	I_C = 10 mAdc, V_{CE} = 10 Vdc	20	150	--
		I_C = 150mAdc, V_{CE} = 10 Vdc*	20	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 150 mAdc, I_B = 15 mAdc	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 150 mAdc, I_B = 15 mAdc	--	2.0	Vdc
Collector-Emitter Sustain Voltage (1)	$V_{CES(sus)}$	I_C = 100 mA, R_{BE} = 0	30	--	Volts
Collector-Emitter Open Base (1) Sustain Voltage	$V_{CEO(sus)}$	I_C = 100 mA, I_B = 0	20	--	Volts
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10 Vdc, I_C = 10 mAdc f = 50 MHz	4.0	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E=0 , f = 100 kHz	--	8.0	pF
Power Input	P_{in}	Test Circuit Fig. 1 P_{out} = 600 mW f = 50 MHz V_{CE} = 13.6 Vdc $I_{C(max)}$ = 125 mA	--	100	mW
Efficiency	η		35	--	%

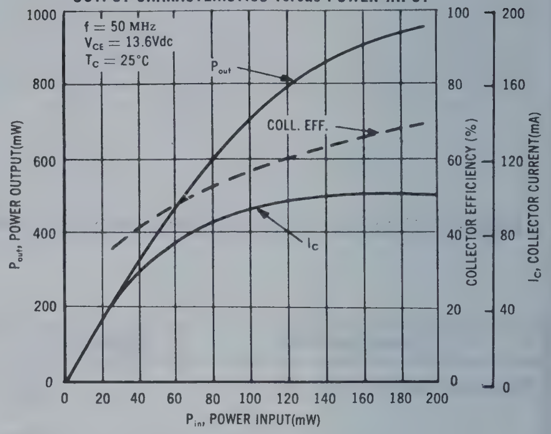
(1) Pulse Width = 100 μs, Duty Cycle = 2%

2N2951, 2N2952 (Continued)

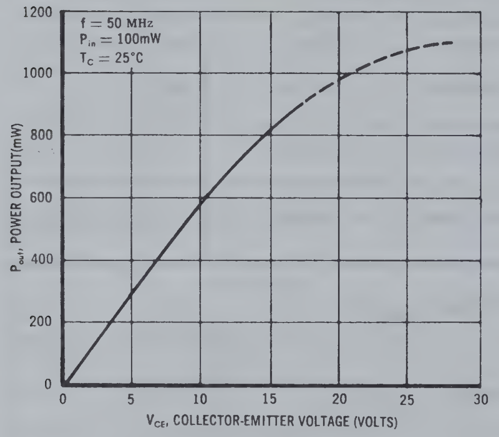
POWER OUTPUT versus FREQUENCY



OUTPUT CHARACTERISTICS versus POWER INPUT



POWER OUTPUT versus COLLECTOR VOLTAGE



POWER OUTPUT versus POWER INPUT

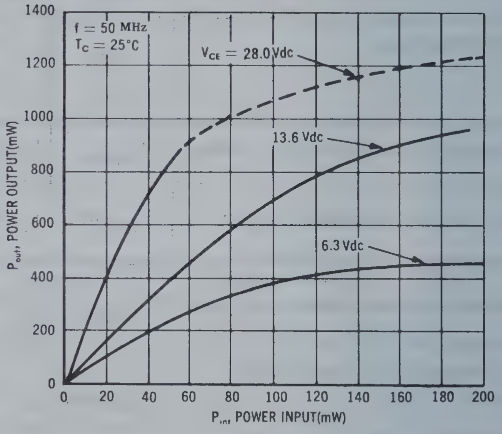
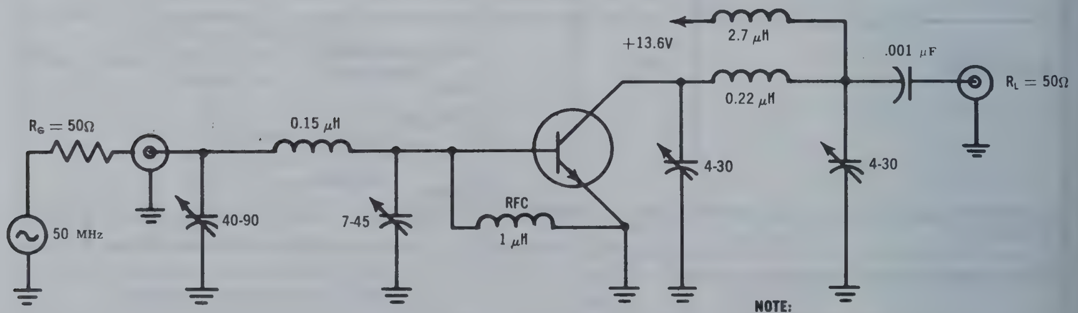


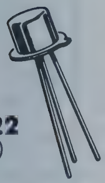
FIGURE 1 — POWER OUTPUT AND POWER GAIN CIRCUIT



R_G = 50Ω
50 MHz
40-90
0.15 μH
7-45
RFC
1 μH
+13.6V
2.7 μH
0.22 μH
4-30
4-30
.001 μF
R_L = 50Ω

NOTE:
GROUND POINT must be kept as close as possible to the transistor emitter lead. Transistor must be mounted with heat sink.

2N2955 (GERMANIUM)
2N2956
2N2957



CASE 22
(TO-18)

Collector connected to case

PNP germanium epitaxial mesa transistors for high-speed switching applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector-Emitter Voltage 2N2955 2N2956 2N2957	V_{CEO}	25 20 18	Vdc
Collector Current	I_C	100	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Total Device Dissipation at 25°C Case Temperature (Derate 4 mW/°C above 25°C)	P_D	300	mW
Total Device Dissipation at 25°C Ambient Temperature (Derate 2 mW/°C above 25°C)	P_D	150	mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)			BV_{CBO}	40	60	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)			BV_{EBO}	3.5	5.0	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, Emitter-Base Termination - Open)	2N2955 2N2956 2N2957	8	BV_{CEO}	25 20 18	35 28 25	--- --- ---	Vdc
Collector-Emitter Reverse Current (V_{CE} = 25 Vdc, V_{EB} = 0.5 Vdc)			I_{CEX}	---	---	10	μAdc
Base Leakage Current (V_{CE} = 25 Vdc, V_{EB} = 0.5 Vdc)		9	I_{BL}	---	---	10	μAdc

ELECTRICAL CHARACTERISTICS (continued)

On Characteristics

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N2955	1	h_{FE}	20	43	---	---
	2N2956	2		30	64	---	
	2N2957	3		60	105	---	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N2955			20	43	60	
	2N2956			40	76	120	
	2N2957			100	130	---	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	2N2956			30	69	---	
	2N2957			60	115	---	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	2N2955	5	$V_{CE\,(sat)}$	---	0.12	0.20	Vdc
	2N2956	6		---	0.12	0.18	
	2N2957	7		---	0.09	0.15	
(I_C = 50 mAdc, I_B = 5 mAdc)	2N2955			---	0.20	0.30	
	2N2956			---	0.16	0.25	
	2N2957			---	0.13	0.20	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N2956			---	0.23	0.34	
	2N2957			---	0.18	0.26	
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	2N2955	4	V_{BE}	---	0.38	0.50	Vdc
	2N2956			---	0.37	0.47	
	2N2957			---	0.36	0.44	
(I_C = 50 mAdc, I_B = 5 mAdc)	2N2955			---	0.51	0.65	
	2N2956			---	0.48	0.60	
	2N2957			---	0.45	0.55	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N2956			---	0.56	0.70	
	2N2957			---	0.52	0.65	

Transient Characteristics

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)		10	C_{ob}	---	2.5	4.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 1 MHz)		10	C_{ib}	---	3.3	---	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 5 Vdc, I_C = 10 mAdc, f = 100 MHz)	2N2955		$\lvert h_{fe} \rvert$	2.0	3.5	---	---
	2N2956			2.5	3.75	---	
	2N2957			3.0	4.0	---	
Delay Time (V_{CC} =12 Vdc, I_{CS} = 50 mAdc, I_{B1} = 5 mAdc, V_{BE} (Off) = 2.2 Vdc)		12	t_d	---	7.0	15	ns
Rise Time (same conditions as t_d)	2N2955	12, 13	t_r	---	25	40	ns
	2N2956			---	18	30	
	2N2957			---	15	25	
Storage Time (V_{CC} = 12 Vdc, I_{CS} = 50 mAdc, I_{B1} = 5 mAdc, I_{B2} = 5 mAdc)	2N2955	12,16	t_s	---	28	40	ns
	2N2956			---	37	55	
	2N2957			---	42	60	
Fall Time (same conditions as t_s)	2N2955	12, 15	t_f	---	25	40	ns
	2N2956			---	18	35	
	2N2957			---	18	35	
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	2N2955	17	Q_T	---	84	---	pc
	2N2956			---	88	---	
	2N2957			---	88	---	
Active Region Time Constant (I_C = 10 mAdc)		14	τ_A	---	2.9	---	ns

FIGURE 1 — CURRENT GAIN CHARACTERISTICS

2N2955

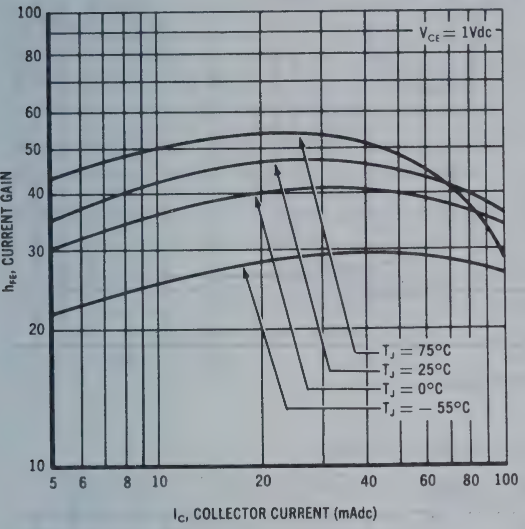


FIGURE 2 — CURRENT GAIN CHARACTERISTICS

2N2956

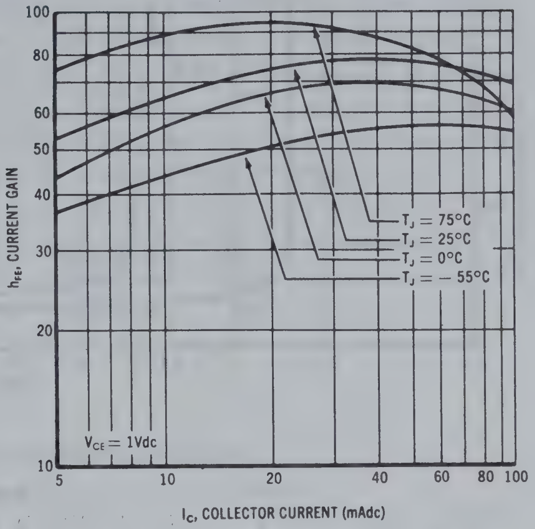


FIGURE 3 — CURRENT GAIN CHARACTERISTICS

2N2957

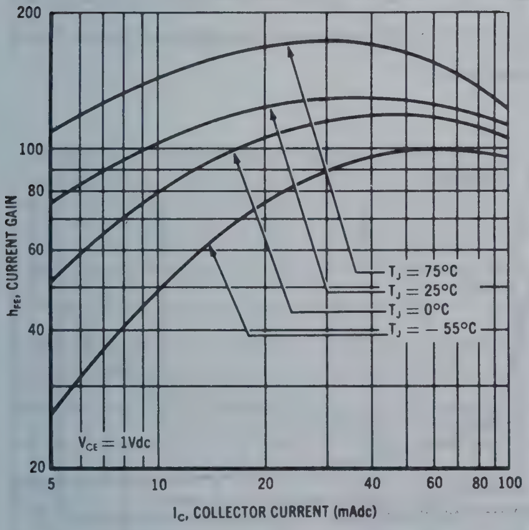
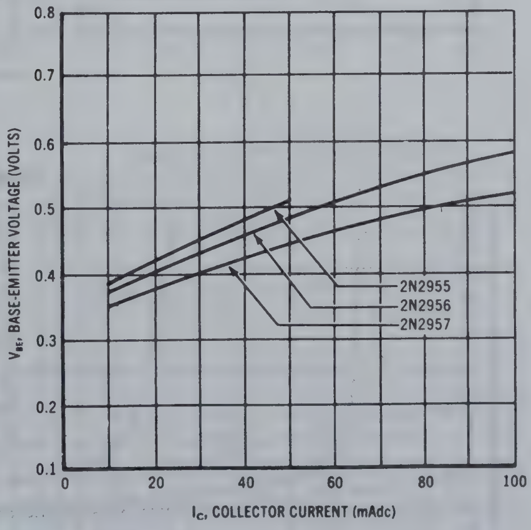


FIGURE 4 — BASE EMITTER VOLTAGE versus COLLECTOR CURRENT



COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

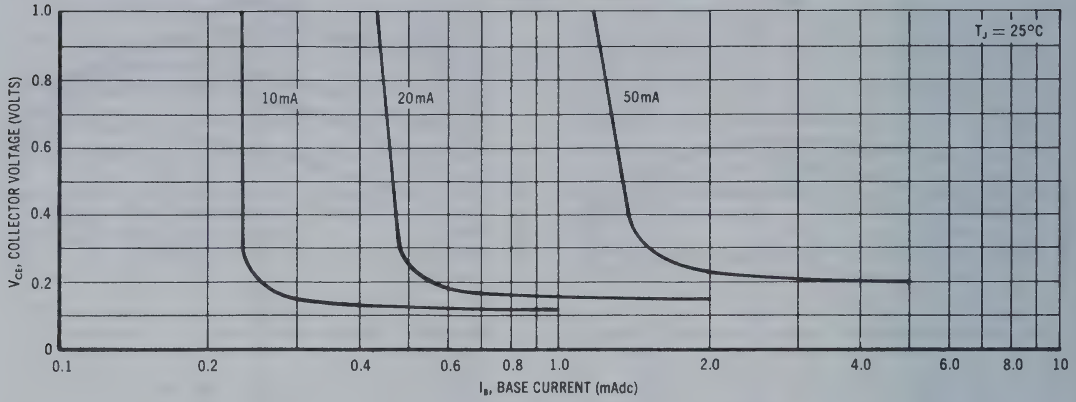


FIGURE 5 —2N2955

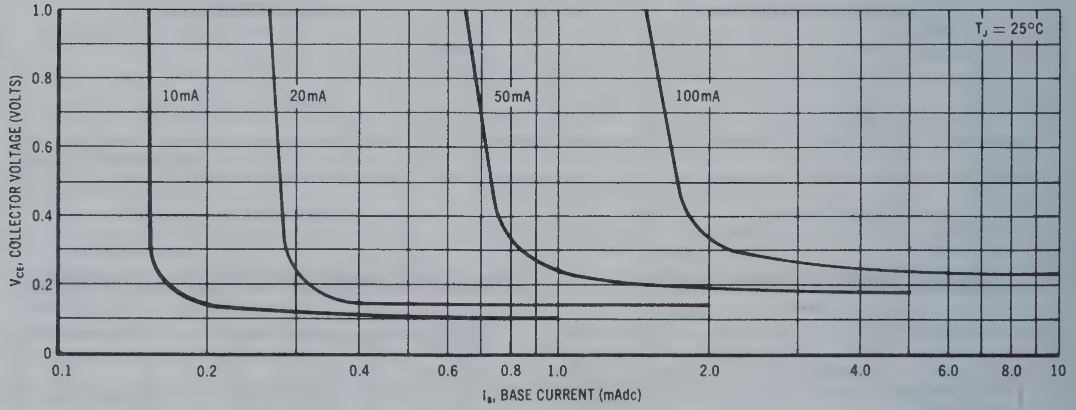


FIGURE 6 —2N2956

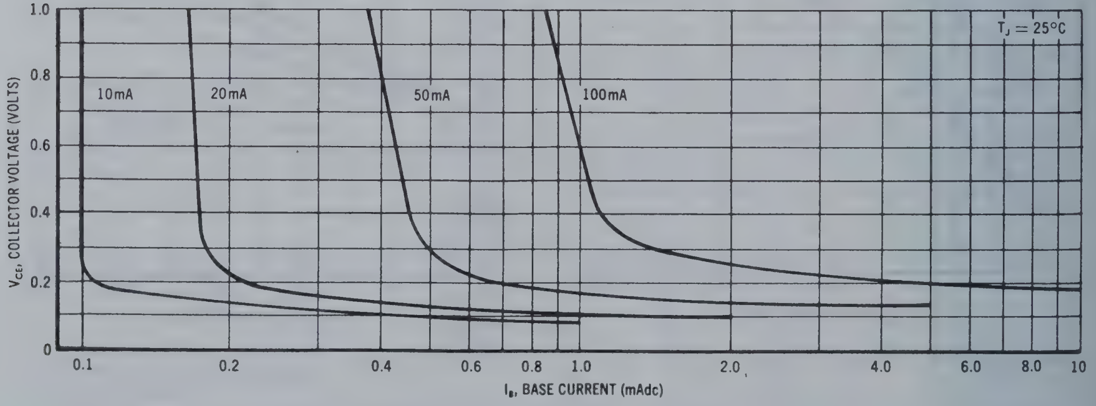
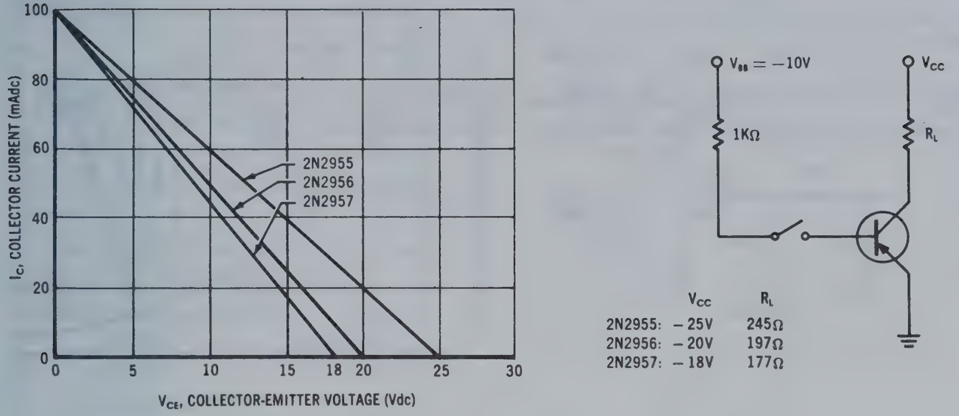


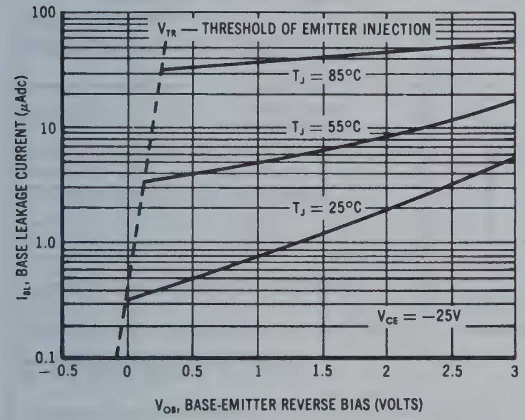
FIGURE 7 —2N2957

FIGURE 8 — OPEN BASE LOAD LINE RATING & TEST CIRCUIT

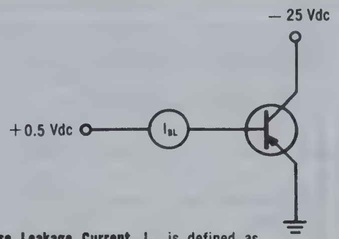


	V_{CC}	R_L
2N2955:	−25V	245Ω
2N2956:	−20V	197Ω
2N2957:	−18V	177Ω

FIGURE 9 — COMMON EMITTER DC LEAKAGE CHARACTERISTICS



BASE LEAKAGE CURRENT TEST CIRCUIT



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of condition.)

FIGURE 10 — JUNCTION CAPACITANCE versus REVERSE BIAS

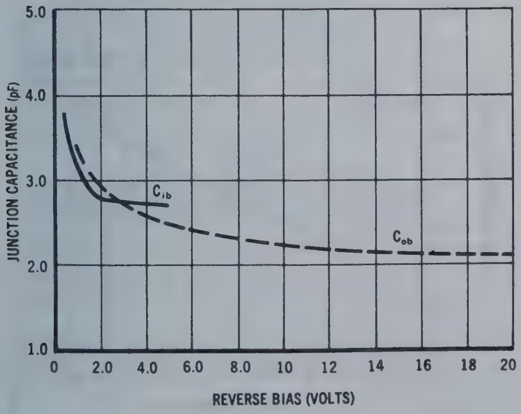


FIGURE 11 — TEMPERATURE COEFFICIENTS

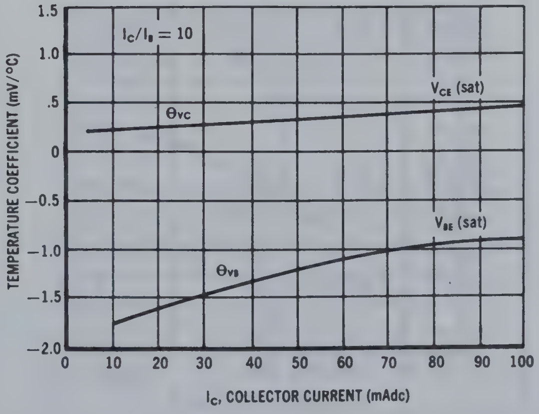


FIGURE 12 — SWITCHING TIME TEST CIRCUIT

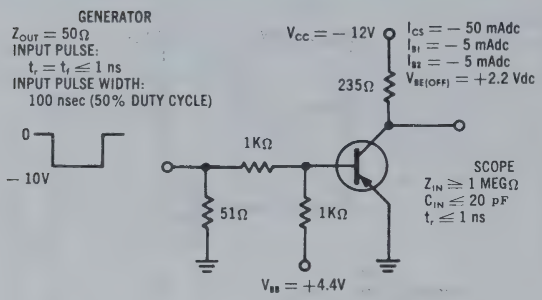

GENERATOR
$Z_{OUT} = 50\Omega$
INPUT PULSE:
$t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH:
100 nsec (50% DUTY CYCLE)
0
– 10V
1KΩ
51Ω
1KΩ
$V_{BB} = +4.4V$
$V_{CC} = -12V$
235Ω
$I_{CS} = -50$ mAdc
$I_{B1} = -5$ mAdc
$I_{B2} = -5$ mAdc
$V_{BE(OFF)} = +2.2$ Vdc
SCOPE
$Z_{IN} \geq 1$ MEGΩ
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns

FIGURE 13 — RISE TIME FACTOR

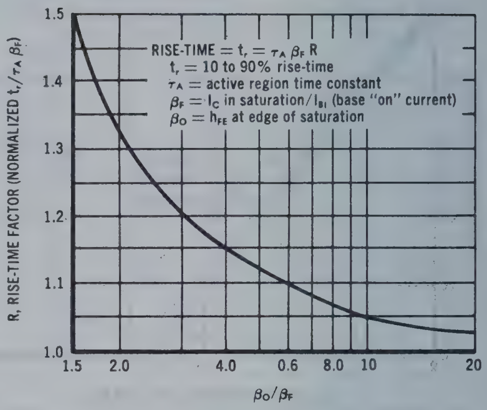


FIGURE 14 — ACTIVE REGION TIME CONSTANT

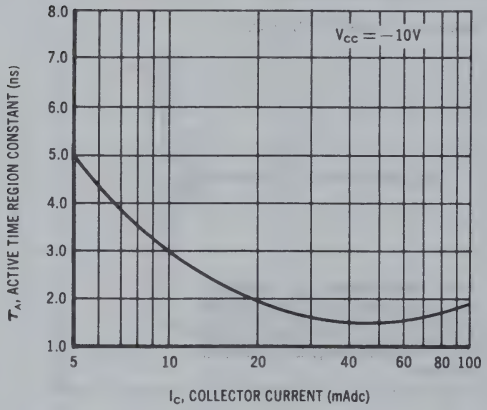


FIGURE 15 — FALL TIME FACTOR

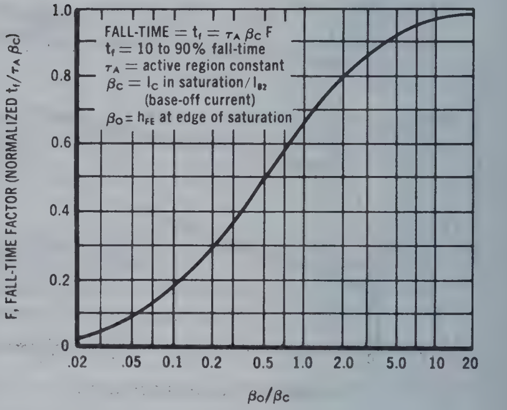


FIGURE 16 — STORAGE TIME

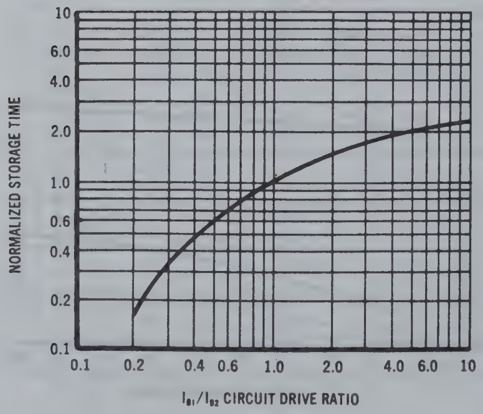
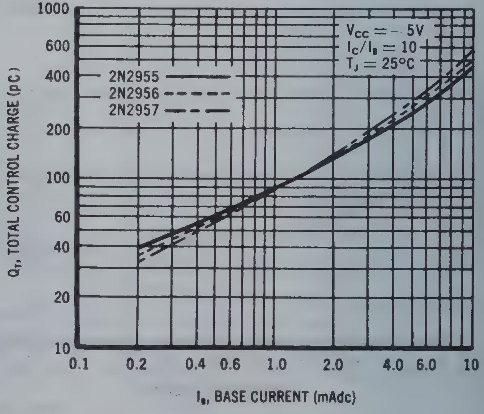


FIGURE 17 — TOTAL CONTROL CHARGE



2N2958 (SILICON)
2N2959
2N3115
2N3116

CASE 31
(TO-5)
CASE 22
(TO-18)

2N2958
2N2959

2N3115
2N3116

Collector connected to case

NPN silicon annular Star transistors for high-speed switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N2958 2N2959 (TO-5)	2N3115 2N3116 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	60	60	Vdc
Collector-Emitter Voltage	V_{CEO}	20	20	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Collector-Current	I_C	600	600	mAdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	3.0 20	1.8 12	Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	0.6 4.00	0.4 2.67	Watts mW/°C
Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 --- ---	 0.025 15	μ Adc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{CEX}	---	.050	μ Adc
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{BL}	---	.050	μ Adc
Collector-Base Breakdown Voltage (I_C = 10 μ Adc, I_E = 0)	BV_{CBO}	60	---	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, pulsed, I_B = 0)	BV_{CEO}	20	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μ Adc, I_C = 0)	BV_{EBO}	5.0	---	Vdc
Collector Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	V_{CE} (sat)	---	0.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	V_{BE} (sat)	---	1.3	Vdc
DC Forward Current Transfer Ratio (I_C = 150 mAdc, 2N2958, 2N3115 V_{CE} = 10 Vdc) 2N2959, 2N3116	h_{FE}	 40 100	 120 300	---
Common-Base Open Circuit Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 100 kHz)	C_{ob}	---	8.0	pF
Delay Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_d	---	20	ns
Rise Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_r	---	75	ns
Storage Time (V_{CC} = 6 V, I_{CS} = 150 mA, I_{B1} = 15 mA, I_{B2} = 15 mA)	t_s	---	300	ns
Fall Time (V_{CC} = 6 V, I_{CS} = 150 mA, I_{B1} = 15 mA, I_{B2} = 15 mA)	t_f	---	200	ns
Current Gain-Bandwidth Product (I_C = 20 mA, V_{CE} = 20 V, f = 100 MHz)	f_T	250	---	MHz

(1) PULSE TEST: Pulse width ≤ 300 μs, duty cycle ≤ 2%

2N2972 thru 2N2979

For Specifications, See 2N2913 Data.

2N3009 (SILICON)
2N3013
2N3013 JAN AVAILABLE
2N3014

NPN silicon epitaxial switching transistors designed for high-speed, medium-power saturated switching applications

CASE 27
(TO-52)

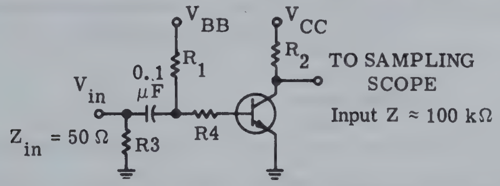
Collector Connected to Case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage* 2N3009, 2N3013 2N3014	V_{CEO}*	 15 20	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage 2N3009 2N3013, 2N3014	V_{EB}	 4.0 5.0	Vdc
Collector Current — Continuous (10 µs pulse) Peak	I_C	200 500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ @ $T_C = 100°C$ Derate above 25°C	P_D	1.20 0.68 6.85	Watts Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

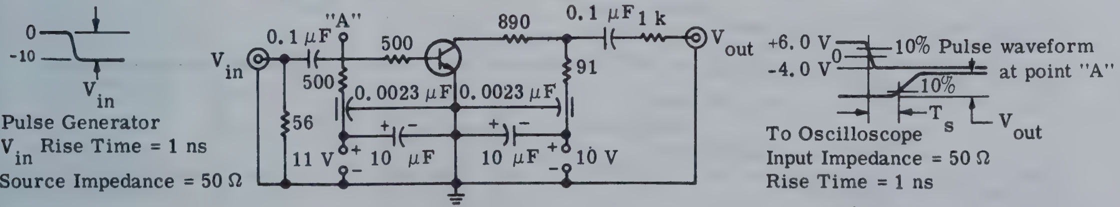
* Applicable from 0.01 mA to 10 mA (Pulsed)

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


V_{BB}
V_{CC}
R_1
R_2
TO SAMPLING SCOPE
Input Z ≈ 100 kΩ
0.1 µF
V_{in}
Z_{in} = 50 Ω
R3
R4

		SWITCHING TEST CIRCUIT VALUES							INPUT PULSE		
Type	Test	V_{in}	V_{BB}	V_{CC}	R_1	R_2	R_3	R_4	t_r	t_f	Pulse Width
2N3009 2N3013	t_{on} & t_{off}	(volts)			(ohms)				(nanoseconds)		
		11	-5.0	15	300	50	75	170	<1.0	<1.0	>100
2N3014	t_{on}	7.0	GND	2.0	100	62	100	2.0 k	<1.0	-	>200
	t_{off}	-13	7.0	2.0							

FIGURE 2 — CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


0
-10
V_{in}
"A"
0.1 µF
500
500
890
0.1 µF
1 k
V_{out}
91
56
0.0023 µF
0.0023 µF
11 V
10 µF
10 µF
10 V
+6.0 V
0
-4.0 V
10%
10%
Pulse waveform at point "A"
T_s
V_{out}

Pulse Generator
V_{in} Rise Time = 1 ns
Source Impedance = 50 Ω

To Oscilloscope
Input Impedance = 50 Ω
Rise Time = 1 ns

V_{in} Rise Time less than 1 ns PW = 300 ns Duty Cycle = 2%

2N3009, 2N3013, 2N3014 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0) 2N3009, 2N3013 2N3014	$BV_{CEO(sus)}$	 15 20	 - -	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0) 2N3009 2N3013, 2N3014	BV_{EBO}	 4.0 5.0	 - -	Vdc
Collector-Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0) 2N3009 (V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +85°C) 2N3009 (V_{CE} = 20 Vdc, V_{BE} = 0) 2N3013, 2N3014 (V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +125°C) 2N3013, 2N3014	I_{CES}	 - - - -	 0.5 15 0.3 40	μAdc
Base Current (V_{CE} = 20 Vdc, V_{BE} = 0) 2N3009 2N3013, 2N3014	I_B	 - -	 0.5 0.3	μAdc
ON CHARACTERISTICS (1)				
DC Current Gain (I_C = 30 mAdc, V_{CE} = 0.4 Vdc) All Types (I_C = 10 mAdc, V_{CE} = 0.4 Vdc) 2N3014 (I_C = 100 mAdc, V_{CE} = 0.5 Vdc) 2N3009, 2N3013 (I_C = 100 mAdc, V_{CE} = 1.0 Vdc) 2N3014 (I_C = 300 mAdc, V_{CE} = 1.0 Vdc) 2N3009, 2N3013 (I_C = 30 mAdc, V_{CE} = 0.4 Vdc, T_A = -55°C) 2N3013, 2N3014	h_{FE}	 30 25 25 25 15 12	 120 - - - - -	
Collector-Emitter Saturation Voltage (I_C = 30 mAdc, I_B = 3.0 mAdc) All Types (I_C = 100 mAdc, I_B = 10 mAdc) 2N3009, 2N3013 (I_C = 100 mAdc, I_B = 10 mAdc) 2N3014 (I_C = 300 mAdc, I_B = 30 mAdc) 2N3009, 2N3013 (I_C = 10 mAdc, I_B = 1.0 mAdc) 2N3014 (I_C = 30 mAdc, I_B = 3.0 mAdc, T_A = +85°C) 2N3009 (I_C = 30 mAdc, I_B = 3.0 mAdc, T_A = +125°C) 2N3013, 2N3014	$V_{CE(sat)}$	 - - - - - - -	 0.18 0.28 0.35 0.50 0.18 0.30 0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 30 mAdc, I_B = 3.0 mAdc) All Types (I_C = 100 mAdc, I_B = 10 mAdc) All Types (I_C = 300 mAdc, I_B = 30 mAdc) 2N3009, 2N3013 (I_C = 10 mAdc, I_B = 1.0 mAdc) 2N3014	$V_{BE(sat)}$	 0.75 - - 0.70	 0.95 1.20 1.70 0.80	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	5.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	8.0	pF
Turn-On Time (Figure 1) ($V_{EB(off)}$ = 5.0 V, V_{CC} = 15 V, I_C = 300 mAdc, I_{B1} ≈ 30 mAdc) 2N3009, 2N3013 ($V_{EB(off)}$ = 0, V_{CC} = 2.0 V, I_C = 30 mAdc, I_{B1} ≈ 3.0 mAdc) 2N3014	t_{on}	 - -	 15 16	ns
Turn-Off Time (Figure 1) (V_{CC} = 15 V, I_C = 300 mAdc, I_{B1} ≈ I_{B2} ≈ 30 mAdc) 2N3009, 2N3013 (V_{CC} = 2.0 V, I_C = 30 mAdc, I_{B1} ≈ I_{B2} ≈ 3.0 mAdc) 2N3014	t_{off}	 - -	 25 25	ns
Charge-Storage Time (Figure 2) (I_C ≈ I_{B1} ≈ I_{B2} ≈ 10 mAdc)	t_s	-	18	ns

(1) Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%.

2N3010 (SILICON)

NPN silicon low-power transistor primarily designed for high-speed, saturated switching applications.

CASE 22
(TO-18)

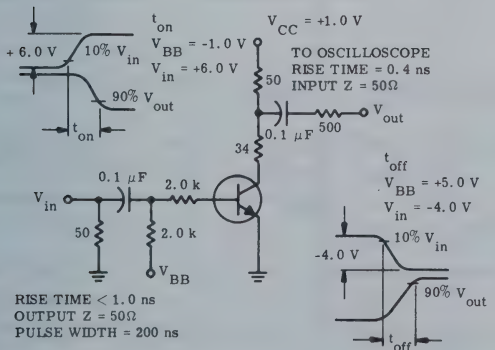
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	6.0	Vdc
Collector-Emitter Voltage	V_{CES}	11	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current — Continuous	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.30 1.71	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

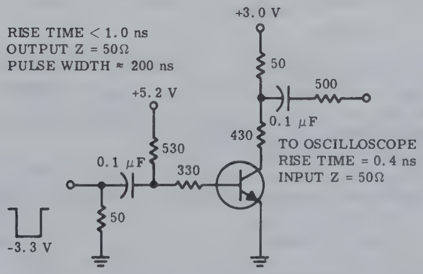
* Applicable from 0.01 mAdc to 10 mAdc (Pulsed).

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


+6.0 V
10% V_{in}
90% V_{out}
t_{on}
t_{on}
V_{BB} = -1.0 V
V_{in} = +6.0 V
V_{CC} = +1.0 V
TO OSCILLOSCOPE
RISE TIME = 0.4 ns
INPUT Z = 50Ω
50
0.1 μF
500
V_{out}
34
0.1 μF
2.0 k
V_{in}
50
2.0 k
V_{BB}
t_{off}
V_{BB} = +5.0 V
V_{in} = -4.0 V
-4.0 V
10% V_{in}
90% V_{out}
t_{off}

RISE TIME < 1.0 ns
OUTPUT Z = 50Ω
PULSE WIDTH = 200 ns

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT


+3.0 V
50
500
0.1 μF
430
TO OSCILLOSCOPE
RISE TIME = 0.4 ns
INPUT Z = 50Ω
+5.2 V
530
0.1 μF
330
50
-3.3 V

RISE TIME < 1.0 ns
OUTPUT Z = 50Ω
PULSE WIDTH ≈ 200 ns

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage(1)	$BV_{CEO(sus)}$*			Vdc
($I_C \Rightarrow 10$ mAdc, $I_B = 0$)		6.0	-	
Collector-Emitter Breakdown Voltage	BV_{CES}			Vdc
($I_C = 10$ μAdc, $V_{BE} = 0$)		11	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
($I_C = 10$ μAdc, $I_E = 0$)		15	-	
Emitter-Base Breakdown Voltage	BV_{EBO}			Vdc
($I_E = 10$ μAdc, $I_C = 0$)		4.0	-	
Collector Cutoff Current	I_{CES}			μAdc
($V_{CE} = 11$ Vdc, $V_{BE} = 0$)		-	10	
($V_{CE} = 5.0$ Vdc, $V_{BE} = 0$)		-	0.1	
($V_{CE} = 5.0$ Vdc, $V_{BE} = 0$, $T_A = +85$°C)		-	5.0	
Base Cutoff Current	I_{BL}			μAdc
($V_{CE} = 11$ Vdc, $V_{EB(off)} = 0$)		-	10	
ON CHARACTERISTICS (1)				
DC Current Gain	h_{FE}			-
($I_C = 1.0$ mAdc, $V_{CE} = 0.4$ Vdc)		15	-	
($I_C = 10$ mAdc, $V_{CE} = 0.4$ Vdc)		25	125	
($I_C = 30$ mAdc, $V_{CE} = 0.4$ Vdc)		15	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
($I_C = 1.0$ mAdc, $I_B = 0.1$ mAdc)		-	0.25	
($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)		-	0.25	
($I_C = 30$ mAdc, $I_B = 3.0$ mAdc)		-	0.38	
($I_C = 10$ mAdc, $I_B = 1.0$ mAdc, $T_A = 85$°C)		-	0.4	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
($I_C = 1.0$ mAdc, $I_B = 0.1$ mAdc)		0.68	0.85	
($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)		0.75	0.95	
($I_C = 30$ mAdc, $I_B = 3.0$ mAdc)		-	1.3	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product	f_T			MHz
($I_C = 10$ mAdc, $V_{CE} = 4.0$ Vdc, f = 100 MHz)		600	-	
Output Capacitance	C_{ob}			pF
($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 140 kHz)		-	3.0	
Input Capacitance	C_{ib}			pF
($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 140 kHz)		-	2.0	
Turn-On Time (Figure 1) ($V_{CC} = 1.0$ Vdc, $V_{BE(off)} = 1.0$ Vdc, $I_C = 10$ mAdc, $I_{B1} \approx 2.0$ mAdc)	t_{on}	-	12	ns
Turn-Off Time (Figure 1)	t_{off}			ns
($V_{CC} = 1.0$ Vdc, $I_C \approx 10$ mAdc, $I_{B1} \approx I_{B2} \approx 1.0$ mAdc)		-	12	
Charge Storage Time (Figure 2)	t_s			ns
($I_C = I_{B1} \approx I_{B2} = 5.0$ mAdc)		-	6.0	

(1) Pulse Test: Pulse Length = 300 μs; Duty Cycle ≤ 2.0%.

2N3011 (SILICON)

NPN silicon low-power transistor primarily designed for high-speed, saturated switching applications.

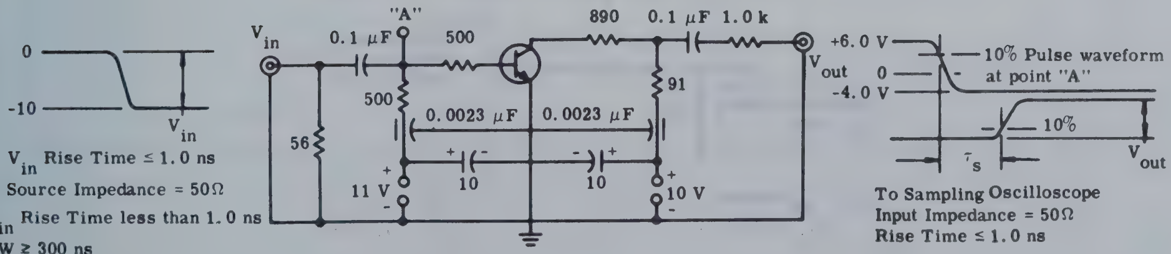
CASE 22
(TO-18)
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	12	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector-Current-Continuous Peak (10 μs Pulse)	I_C	200 500	mAdc
Total Device Dissipation @ T_A=25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C=25°C T_C=100°C Derate above 25°C	P_D	1.20 0.68 6.85	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

* Applicable from 0.01 mA to 10 mA (Pulsed)

FIGURE 1 — CHARGE-STORAGE TIME TEST CIRCUIT


0
-10
V_{in}
V_{in}
"A"
0.1 μF
500
890
0.1 μF
1.0 k
500
56
0.0023 μF
0.0023 μF
91
10
10
11 V
10 V
+
-
V_{out}
+6.0 V
0
-4.0 V
10% Pulse waveform at point "A"
10%
τ_s
V_{out}

V_{in} Rise Time ≤ 1.0 ns
Source Impedance = 50Ω
V_{in} Rise Time less than 1.0 ns
PW ≥ 300 ns
Duty Cycle ≤ 2.0%

To Sampling Oscilloscope
Input Impedance = 50Ω
Rise Time ≤ 1.0 ns

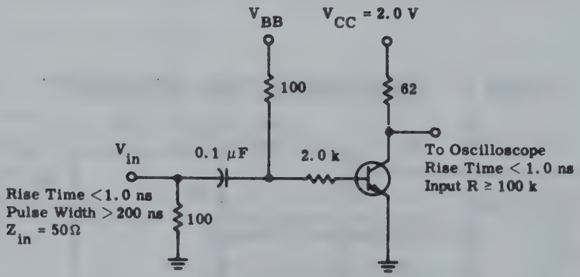
2N3011 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage [1] (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	12	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 µAdc, V_{BE} = 0)	BV_{CES}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0) (V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +85°C)	I_{CES}	- -	0.4 10	µAdc
Base Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	I_{BL}	-	0.4	µAdc
ON CHARACTERISTICS [1]				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.35 Vdc) (I_C = 30 mAdc, V_{CE} = 0.4 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30 25 12	120 - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +85°C)	$V_{CE(sat)}$	- - - -	0.20 0.25 0.50 0.30	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	0.72 - -	0.87 1.15 1.60	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	4.0	pF
Turn-On Time (Figure 2) (V_{CC} = 2.0 Vdc, $V_{EB(off)}$ = 0, $I_C \approx$ 30 mAdc, $I_{B1} \approx$ 3.0 mAdc)	t_{on}	-	15	ns
Turn-Off Time (Figure 2) (V_{CC} = 2.0 Vdc, I_C = 30 mAdc, $I_{B1} \approx -I_{B2} \approx$ 3.0 mAdc)	t_{off}	-	20	ns
Charge Storage Time (Figure 1) ($I_C = I_{B1} \approx -I_{B2} \approx$ 10 mAdc)	t_s	-	13	ns

[1] Pulse Test: Pulse Length = 300 µs, Duty Cycle ≤ 2.0%.

FIGURE 2 – TURN-ON AND TURN-OFF TIME TEST CIRCUIT



T_{on}: V_{BB} Grounded
V_{in} = 7.0 V

T_{off}: V_{BB} = 7.0 V
V_{in} = -13 V

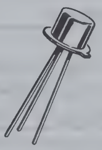
2N3012 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for use in medium-speed saturated switching applications.

- Collector-Emitter Sustaining Voltage —
  $V_{CEO(sus)}$ = 12 Vdc @ I_C = 10 mAdc
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.15 Vdc @ I_C = 10 mAdc

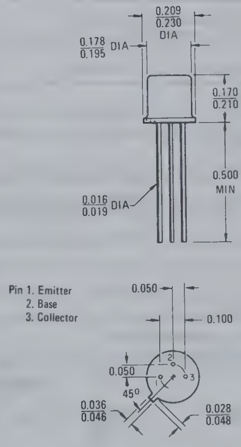
PNP SILICON
SWITCHING
TRANSISTOR



*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current — Continuous	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.85	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
Pin 1. Emitter
2. Base
3. Collector
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

Collector Connected to Case
CASE 22 (1)
TO-18

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage(1) (I_C = 10 mAdc, I_B = 0) (Emitter-Base Termination — Open Base)	$V_{CEO(sus)}$	12	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	12	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	—	Vdc
Collector Cutoff Current	I_{CES}			
(V_{CE} = 6.0 Vdc, V_{BE} = 0)		—	80	nAdc
(V_{CE} = 6.0 Vdc, V_{BE} = 0, T_A = +85°C)		—	5.0	μAdc
Base Current (V_{CE} = 6.0 Vdc, V_{BE} = 0)	I_B	— —	30	nAdc
ON CHARACTERISTICS				
DC Current Gain(1)	h_{FE}			—
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		25	—	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc)		30	120	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		20	—	
Collector-Emitter Saturation Voltage(1)	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		—	0.15	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		—	0.2	
(I_C = 30 mAdc, I_B = 3.0 mAdc, T_A = +85°C)		—	0.4	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	0.5	
Base-Emitter Saturation Voltage(1)	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		0.78	0.98	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		0.85	1.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	1.7	
SMALL-SIGNAL CHARACTERISTICS				
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	6.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	6.0	pF
Small-Signal Current Gain (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	4.0	—	—
SWITCHING CHARACTERISTICS (See Figure 1)				
Turn-On Time (V_{CC} = 2.0 Vdc, I_C≈30 mAdc, I_{B1}≈1.5 mAdc)	t_{on}	—	60	ns
Turn-Off Time (V_{CC} = 2.0 Vdc, I_C≈30 mAdc, I_{B1} = I_{B2}≈1.5 mAdc)	t_{off}	—	75	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

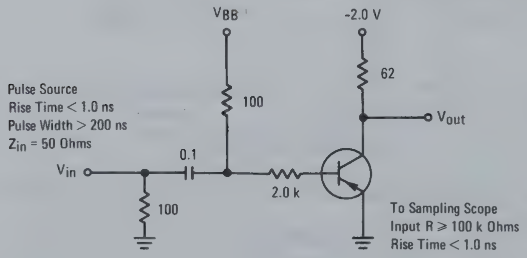


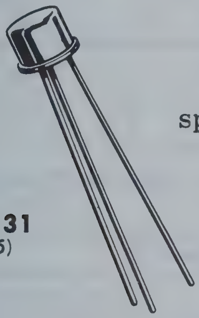
FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

Notes:
(1) Collector Current≈30 mA
(2) Turn On and Turn Off Base Currents≈1.5 mA
(3) t_{on} V_{BB} = +3.0 V V_{in} = −7.0 V
t_{off} V_{BB} = −4.0 V V_{in} = +6.0 V

2N3013
2N3014

For Specifications, See 2N3009 Data.

2N3015 (SILICON)



CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	30	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	800 4.6	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.0 17.2	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

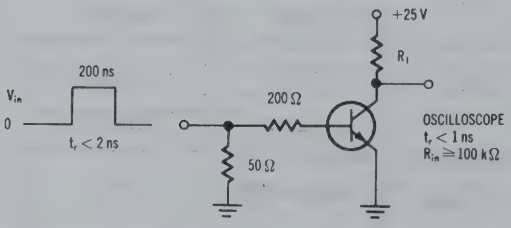
*Applicable from 1.0 mA to 30 mA (Pulsed)

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* ($I_C = 30$ mAdc, $I_B = 0$)	$BV_{CEO(sus)}$*	30	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu$Adc, $I_E = 0$)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	5.0	—	Vdc
Collector-Cutoff Current ($V_{CE} = 30$ Vdc, $V_{BE} = 0$)	I_{CES}	—	0.2	μAdc
Collector-Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$, $T_A = 125^\circ C$)	I_{CBO}	—	200	μAdc
Base Leakage Current ($V_{CE} = 30$ Vdc, $V_{BE} = 0$)	I_{BL}	—	0.2	μAdc
ON CHARACTERISTICS				
DC Current Gain* ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 300$ mAdc, $V_{CE} = 0.7$ Vdc)	h_{FE}*	 30 10	 120 —	—
Collector-Emitter Saturation Voltage* ($I_C = 150$ mAdc, $I_B = 15$ mAdc) ($I_C = 500$ mAdc, $I_B = 50$ mAdc)	$V_{CE(sat)}$*	 — —	 0.4 1.0	Vdc
Base-Emitter Saturation Voltage* ($I_C = 150$ mAdc, $I_B = 15$ mAdc) ($I_C = 500$ mAdc, $I_B = 50$ mAdc)	$V_{BE(sat)}$*	 — —	 1.2 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, $f = 100$ MHz)	f_T	250	—	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, $f = 140$ kHz)	C_{ob}	—	8.0	pF
Turn-On Time (Figure 1) ($V_{CC} = 25$ Vdc, $I_C \approx 300$ mAdc, $I_{B1} \approx 30$ mAdc) ($V_{CC} = 25$ Vdc, $I_C \approx 500$ mAdc, $I_{B1} \approx 50$ mAdc)	t_{on}	 — —	 40 40	ns
Turn-Off Time (Figure 2) ($V_{CC} = 25$ Vdc, $I_C \approx 300$ mAdc, $I_{B1} \approx I_{B2} = 30$ mAdc) ($V_{CC} = 25$ Vdc, $I_C \approx 500$ mAdc, $I_{B1} \approx I_{B2} = 50$ mAdc)	t_{off}	 — —	 60 60	ns

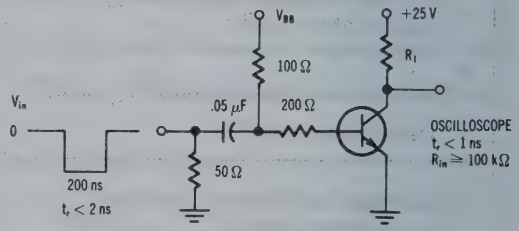
*Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%

FIGURE 1 — TURN-ON TIME TEST CIRCUIT



I_C mA	V_{in} Volts	R_l ohms
300	7.0	80
500	11	48

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT



I_C mA	V_{in} Volts	V_{BB} Volts	R_l ohms
300	−13	10	80
500	−21	16	48

2N3019 (SILICON)
2N3020

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistors designed for high-current, high-frequency amplifier applications.

MAXIMUM RATINGS

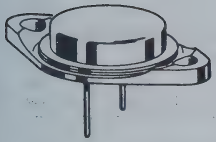
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	140	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 4.6	W mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6	W mW/°C
Operating Junction Temperature Range	T_J	-65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	80	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	140	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	—	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0) (V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.010 10	μAdc
Emitter Cutoff Current (V_{BE} = 5 Vdc, I_C = 0)	I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020	h_{FE}	50 30	— 100	—
(I_C = 10 mAc, V_{CE} = 10 Vdc) 2N3019 2N3020		90 40	— 120	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020		100 40	300 120	
(I_C = 150 mAdc, V_{CE} = 10 Vdc, T_C = -55°C) 2N3019		40	—	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020		50 30	— 100	
(I_C = 1 Adc, V_{CE} = 10 Vdc) Both Types		15	—	
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$	— —	0.2 0.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	—	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz) 2N3019 2N3020	f_T	100 80	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	12	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)	C_{ib}	—	60	pF
Small-Signal Current Gain (I_C = 1mAdc, V_{CE} = 5 Vdc, f = 1 kHz) 2N3019 2N3020	h_{fe}	80 30	400 200	—
Collector-Base Time Constant (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 4 MHz)	$r_b'C_c$	—	400	ps
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, f = 1 kHz, R_S = 1 kohm) 2N3019	NF	—	4.0	dB

(1) Pulse Test: Pulse Width ≦ 300 μs, duty cycle ≦ 1%

2N3021 thru 2N3026 (SILICON)



CASE 1
(TO-3)

PNP silicon power transistors for Class C power amplifiers, high-current core switching and high-speed switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3021 2N3024	2N3022 2N3025	2N3023 2N3026	Unit
Collector-Base Voltage	V_{CB}	30	45	60	Volts
Collector-Emitter Voltage	V_{CEO}	30	45	60	Volts
Emitter-Base Voltage	V_{EB}	4.0			Volts
Collector Current	I_C	3.0			Amp
Base Current	I_B	0.5			Amp
Power Dissipation	P_D	25			Watts
Junction Operating Temperature Range	T_J	-65 to +175			°C

2N3021 thru 2N3026 (continued)

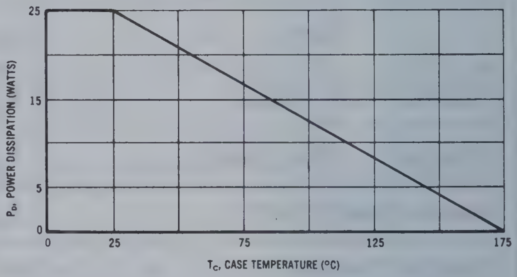
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified)

Characteristics		Symbol	Min	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 4 Vdc)			—	1.0	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 25 Vdc, V_{BE} = 2 Vdc)	2N3021, 2N3024		—	0.2	
(V_{CE} = 40 Vdc, V_{BE} = 2 Vdc)	2N3022, 2N3025		—	0.2	
(V_{CE} = 54 Vdc, V_{BE} = 2 Vdc)	2N3023, 2N3026		—	0.2	
(V_{CE} = 15 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3021, 2N3024		—	2.0	
(V_{CE} = 25 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3022, 2N3025		—	2.0	
(V_{CE} = 35 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3023, 2N3026		—	2.0	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3021, 2N3024		30	—	
(I_C = 50 mAdc, I_B = 0)	2N3022, 2N3025		45	—	
(I_C = 20 mAdc, I_B = 0)	2N3023, 2N3026		60	—	
DC Current Gain		h_{FE}			—
(I_C = 1.0 Adc, V_{CE} = 2 Vdc)	2N3021, 2N3022, 2N3023		20	60	
	2N3024, 2N3025, 2N3026		50	180	
Collector-Emitter Saturation Voltage		$V_{CE\,(sat)}$			Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3021, 2N3022, 2N3023		—	1.5	
	2N3024, 2N3025, 2N3026		—	1.0	
Base-Emitter Saturation Voltage		$V_{BE\,(sat)}$			Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)			—	1.5	
Small Signal Current Gain		h_{fe}			—
(I_C = 0.5 Adc, V_{CE} = 15 Vdc, f = 30 MHz)			2.0	—	
Switching Times					ns
(I_C = 1 Adc, I_{B1} = I_{B2} = 100 mAdc)		$t_d + t_r$	—	100	
		t_s	—	325	
		t_f	—	75	

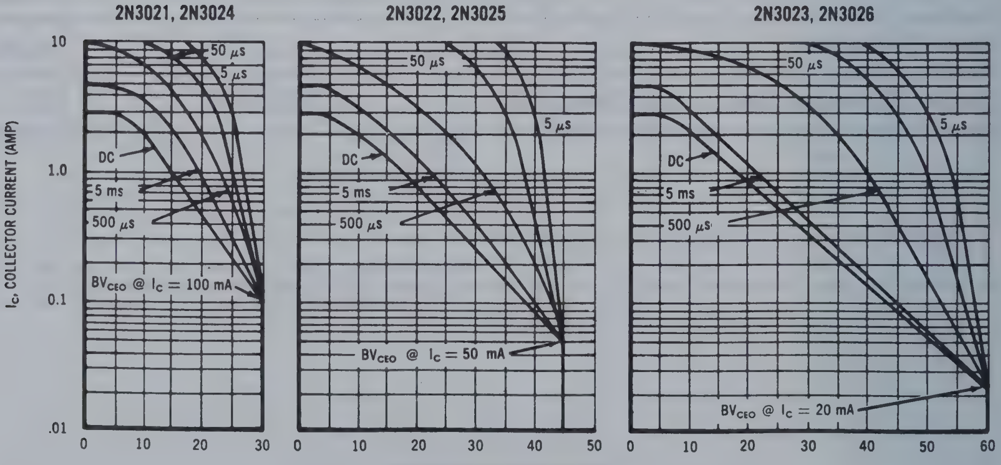
*Perform tests using sweep method to prevent heating.

POWER-TEMPERATURE DERATING CURVE

THESE TRANSISTORS ARE ALSO SUBJECT TO SAFE AREA CURVES AS INDICATED BOTH LIMITS ARE APPLICABLE AND MUST BE OBSERVED



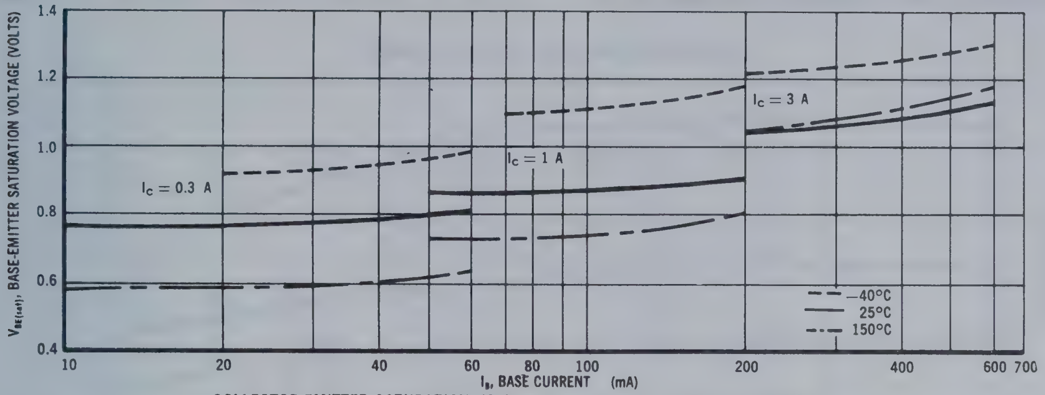
SAFE OPERATING AREAS



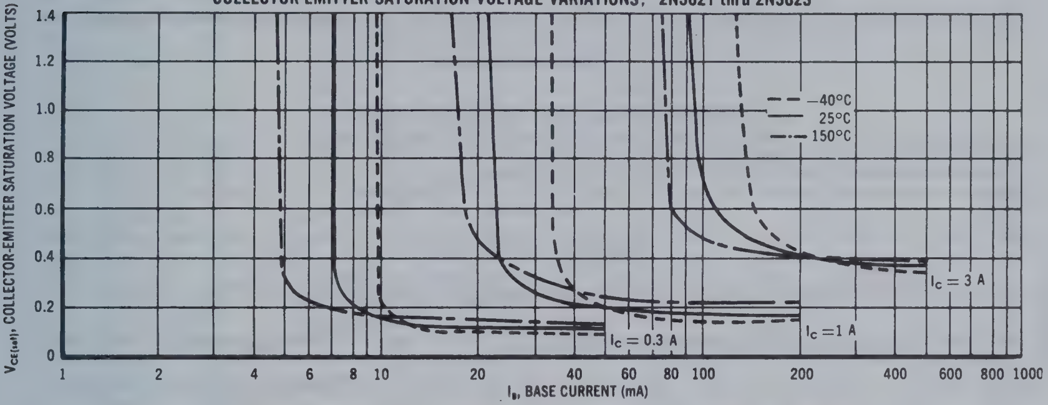
The Safe Operating Area Curves indicate I_C - V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the average power derating curve is also taken into consideration to insure operation below the maximum junction temperature.

2N3021 thru 2N3026 (continued)

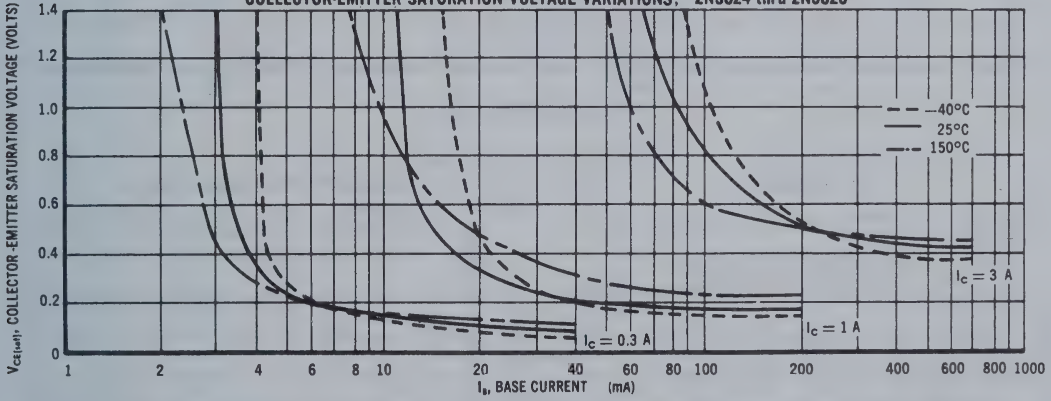
BASE-EMITTER SATURATION VOLTAGE VARIATIONS



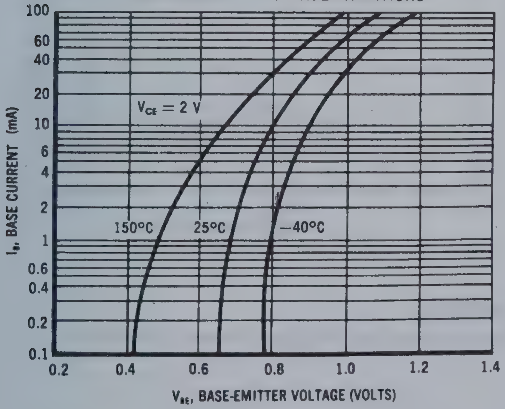
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS, 2N3021 thru 2N3023



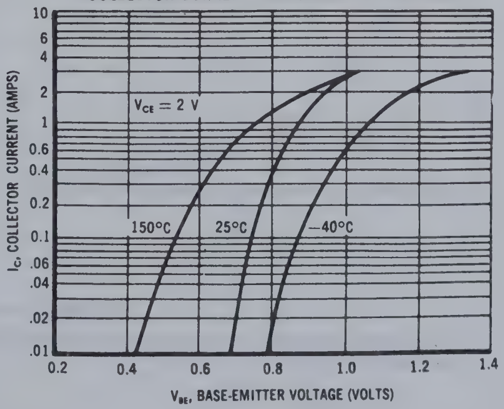
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS, 2N3024 thru 2N3026

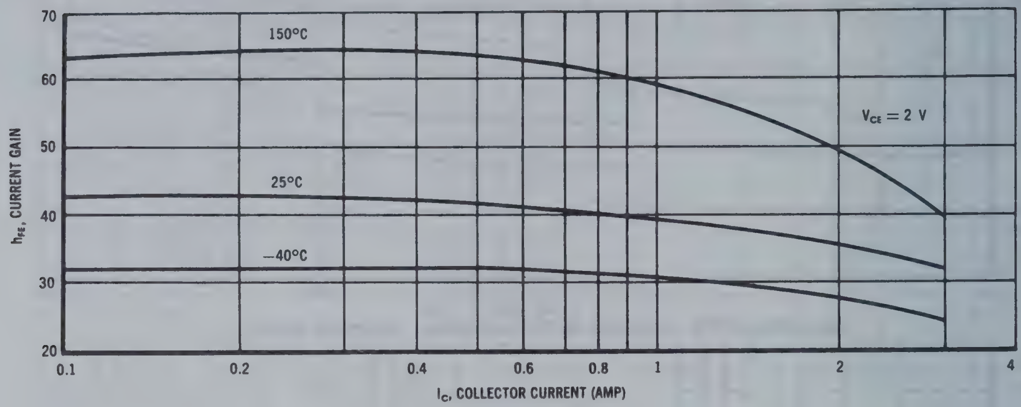


BASE CURRENT — VOLTAGE VARIATIONS

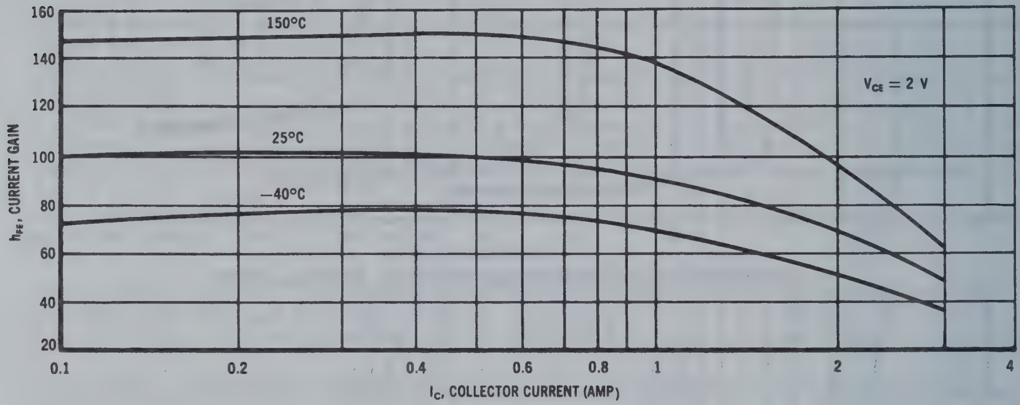


COLLECTOR CURRENT vs BASE-EMITTER VOLTAGE

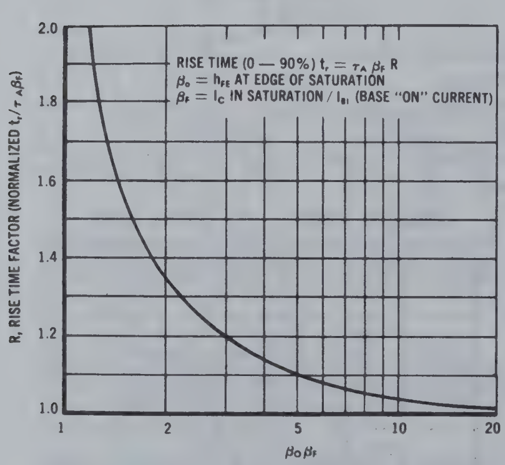




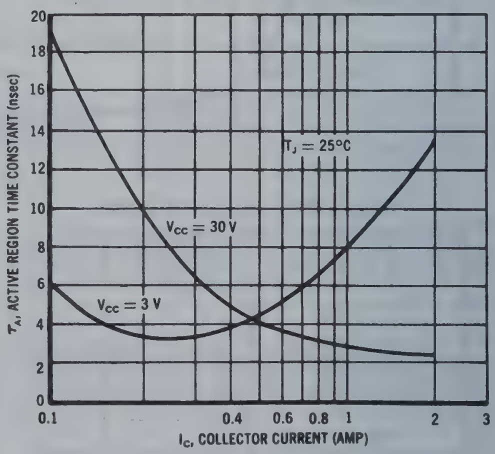
CURRENT GAIN VARIATIONS, 2N3021 thru 2N3023



CURRENT GAIN VARIATIONS, 2N3024 thru 2N3026



RISE TIME FACTOR

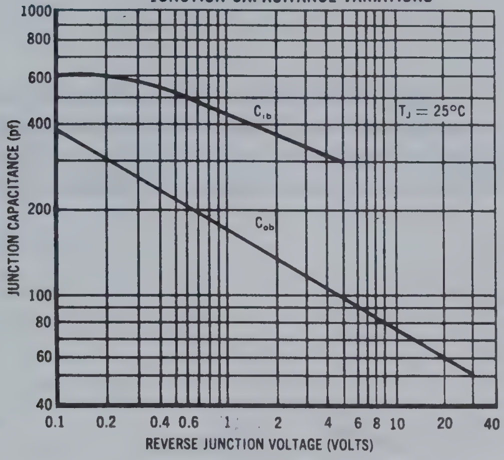


ACTIVE REGION TIME CONSTANT

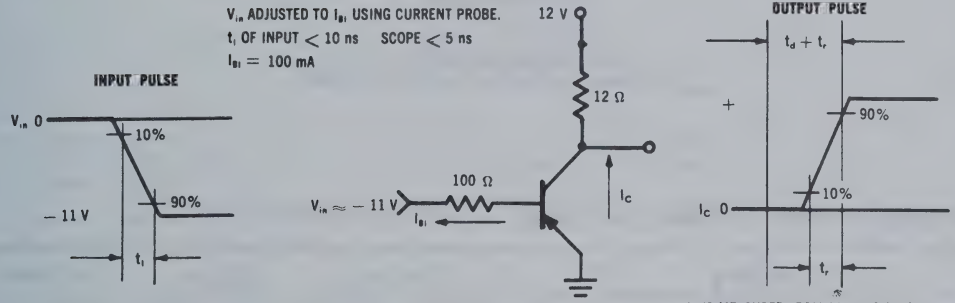
SWITCHING TIME EQUATIONS

Using charge control theory and data given with this transistor, switching times for a wide variety of conditions can be readily computed.

JUNCTION CAPACITANCE VARIATIONS



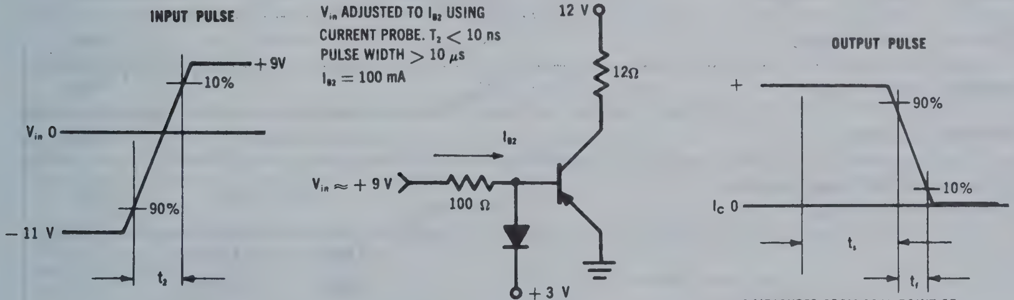
TURN-ON TIME TEST CONDITIONS


INPUT PULSE
V_{in} 0
10%
90%
− 11 V
t_r
12 V
12 Ω
100 Ω
V_{in} ≈ − 11 V
I_{B1}
I_C
OUTPUT PULSE
t_d + t_r
+
90%
10%
I_C 0
t_r

V_{in} ADJUSTED TO I_{B1} USING CURRENT PROBE.
t_r OF INPUT < 10 ns SCOPE < 5 ns
$I_{B1} = 100$ mA

t_d IS MEASURED FROM 10% POINT OF V_{in}

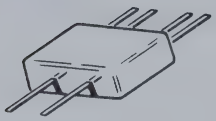
TURN-OFF TIME TEST CONDITIONS


INPUT PULSE
+ 9V
10%
V_{in} 0
90%
− 11 V
t₂
12 V
12Ω
I_{B2}
V_{in} ≈ + 9 V
100 Ω
+ 3 V
OUTPUT PULSE
+
90%
10%
I_C 0
t_s
t_f

V_{in} ADJUSTED TO I_{B2} USING CURRENT PROBE. $T_2 < 10$ ns
PULSE WIDTH $> 10\ \mu s$
$I_{B2} = 100$ mA

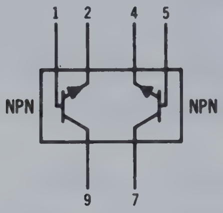
t_s IS MEASURED FROM 90% POINT OF V_{in}

2N3043 thru 2N3048 (SILICON)



CASE 610-02

Dual NPN silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N3049, 2N3050, for metal can see 2N2639-2N2644 series.



Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	250 1.43	350 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	700 4.0	1400 8.0	mW mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0)		$BV_{CEO(sus)}$	45	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0) (V_{CB} = 45 Vdc, I_E = 0, T_A = +150°C)		I_{CBO}	— —	0.010 10	μAdc
Emitter-Base Cutoff Current (V_{EB} = 4 Vdc, I_C = 0)		I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS					
DC Current Gain (1) (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3044, 2N3045 2N3046, 2N3047, 2N3048	h_{FE}	100 50	300 200	—
(I_C = 1 mAdc, V_{CE} = 5 Vdc)	2N3043, 2N3044, 2N3045 2N3046, 2N3047, 2N3048		130 65	— —	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)		$V_{CE(sat)}$	—	1.0	Vdc
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 5 Vdc)		$V_{BE(on)}$	0.6	0.8	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)		f_T	30	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	8.0	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045 2N3046, 2N3047, 2N3048	h_{ie}	3.2k 1.6k	19k 13k	Ohms
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045 2N3046, 2N3047, 2N3048	h_{fe}	130 65	600 400	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045 2N3046, 2N3047, 2N3048	h_{oe}	— —	100 70	μmhos
Noise Figure (I_C = 10 μAdc, V_{CE} = 5 Vdc, R_S = 10k ohms, Bandwidth = 10 Hz to 15.7 kHz)		NF	—	5.0	dB
MATCHING CHARACTERISTICS					
DC Current Gain Ratio** (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3046 2N3044, 2N3047	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3046 2N3044, 2N3047	$\lvert V_{BE1} - V_{BE2} \rvert$	— —	5.0 10	mVdc
Base Voltage Differential Temperature Gradient (I_C = 10 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C)	2N3043, 2N3046 2N3044, 2N3047	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— —	10 20	μV/°C

(1) Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

2N3053 (SILICON)

CASE 31
(TO-5)

NPN silicon annular transistor designed for medium-current switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current-Continuous	I_C	700	mAdc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	5.0 28.6	Watts $mW/^oC$
Operating Junction Temperature Range	T_J	200	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	BV_{CEO}	40	—	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 100$ mAdc, $R_{BE} = 10$ ohms)	BV_{CER}	50	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu Adc$, $I_C = 0$)	BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current ($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	I_{CEX}	—	0.25	μAdc
Base Cutoff Current ($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	I_{BL}	—	0.25	μAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc) ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc)(1)	h_{FE}	25 50	— 250	—
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$	—	1.4	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$	—	1.7	Vdc
Base-Emitter On Voltage ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc)	$V_{BE(on)}$	—	1.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, $f = 20$ MHz)	f_T	100	—	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, $f = 140$ kHz)	C_{ob}	—	15	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, $f = 140$ kHz)	C_{ib}	—	80	pF

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

2N3054A (SILICON)

MEDIUM-POWER NPN SILICON TRANSISTOR

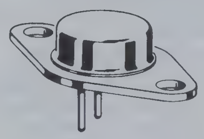
. . . designed for general purpose switching and amplifier applications.

- Aluminum TO-66 Package for Better Power Handling Capability — 75 Watts @ $T_C = 25^oC$
- Excellent Safe Operating Area
- DC Current Gain Specified to 3.0 Amperes
- Complement to PNP Type 2N6049

4 AMPERE

POWER TRANSISTOR
NPN SILICON

55 VOLTS
75 WATTS



*MAXIMUM RATINGS

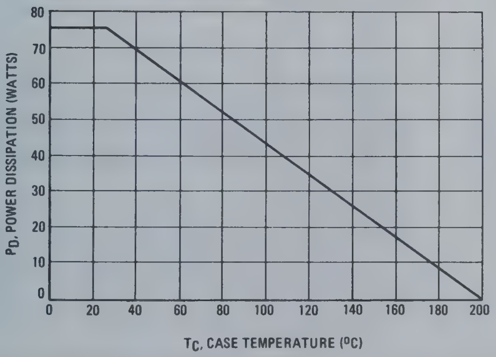
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	55	Vdc
Collector-Emitter Voltage (R_{BE} = 100 Ω)	V_{CER}	60	Vdc
Collector-Base Voltage	V_{CB}	90	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current — Continuous	I_C	4.0	Adc
Peak		10	
Base Current	I_B	2.0	Adc
Total Device Dissipation @ $T_C = 25^oC$	P_D	75	Watts
Derate above 25^oC		0.43	$W/^oC$
Operating and Storage Junction, Temperature Range	T_J, T_{stg}	-65 to +200	^oC

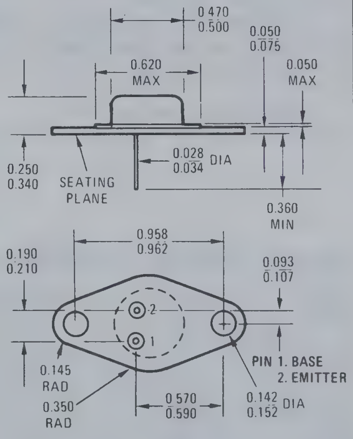
*Indicates JEDEC Registered Data

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.33	$^oC/W$

FIGURE 1 – POWER-TEMPERATURE DERATING





0.470
0.500
0.050
0.075
0.620
MAX
0.050
MAX
0.250
0.340
SEATING
PLANE
0.028
0.034 DIA
0.360
MIN
0.958
0.962
0.190
0.210
0.093
0.107
2
1
PIN 1. BASE
2. EMITTER
0.145
RAD
0.350
RAD
0.570
0.590
0.142
0.152 DIA

All JEDEC dimensions and notes apply

Collector connected to case

CASE 80-02
TO-66

ELECTRICAL CHARACTERISTICS ($T_C = 25^\circ$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
***OFF CHARACTERISTICS**				
Collector-Emitter Sustaining Voltage (1) ($I_C = 100$ mAdc, $I_B = 0$)	$V_{CEO(sus)}$	55	–	Vdc
Collector-Emitter Sustaining Voltage (1) ($I_C = 100$ mAdc, $R_{BE} = 100\ \Omega$)	$V_{CER(sus)}$	60	–	Vdc
Collector Cutoff Current ($V_{CE} = 30$ Vdc, $I_B = 0$)	I_{CEO}		500	µAdc
Collector Cutoff Current ($V_{CE} = 90$ Vdc, $V_{BE(off)} = 1.5$ Vdc) ($V_{CE} = 90$ Vdc, $V_{BE(off)} = 1.5$ Vdc, $T_C = 150^\circ$C)	I_{CEX}	– –	1.0 6.0	mAdc
Emitter Cutoff Current ($V_{BE} = 7.0$ Vdc, $I_C = 0$)	I_{EBO}	–	1.0	mAdc
***ON CHARACTERISTICS** (1)				
DC Current Gain ($I_C = 0.5$ Adc, $V_{CE} = 4.0$ Vdc) ($I_C = 3.0$ Adc, $V_{CE} = 4.0$ Vdc)	h_{FE}	25 5.0	100 –	–
Collector-Emitter Saturation Voltage ($I_C = 500$ mAdc, $I_B = 50$ mAdc) ($I_C = 3.0$ Adc, $I_B = 1.0$ Adc)	$V_{CE(sat)}$	– –	1.0 6.0	Vdc
Base-Emitter On Voltage ($I_C = 500$ mAdc, $V_{CE} = 4.0$ Vdc)	$V_{BE(on)}$	–	1.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 200$ mAdc, $V_{CE} = 10$ Vdc)	f_T	3.0	–	MHz
*Small-Signal Current Gain ($I_C = 100$ mAdc, $V_{CE} = 4.0$ Vdc, f = 1.0 kHz)	h_{fe}	25	180	–
*Common-Emitter Cutoff Frequency ($I_C = 100$ mAdc, $V_{CE} = 4.0$ Vdc)	f_{hfe}	30	--	kHz

*Indicates JEDEC Registered Data
(1) Pulse test: Pulse Width ⩽300 µs, Duty Cycle ⩽2.0%

FIGURE 2 – SWITCHING TIME EQUIVALENT TEST CIRCUIT

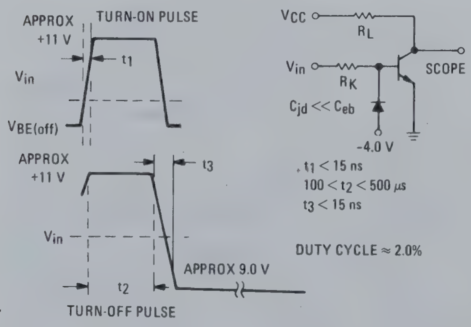

APPROX +11 V
TURN-ON PULSE
t1
Vin
VBE(off)
APPROX +11 V
t3
Vin
APPROX 9.0 V
t2
TURN-OFF PULSE
VCC
RL
Vin
RK
SCOPE
Cjd << Ceb
-4.0 V
t1 < 15 ns
100 < t2 < 500 µs
t3 < 15 ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 – TURN-ON TIME

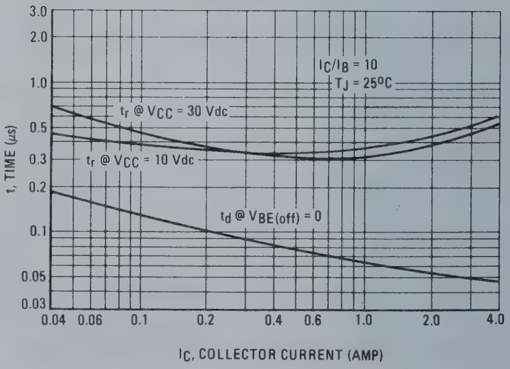


FIGURE 4 – THERMAL RESPONSE

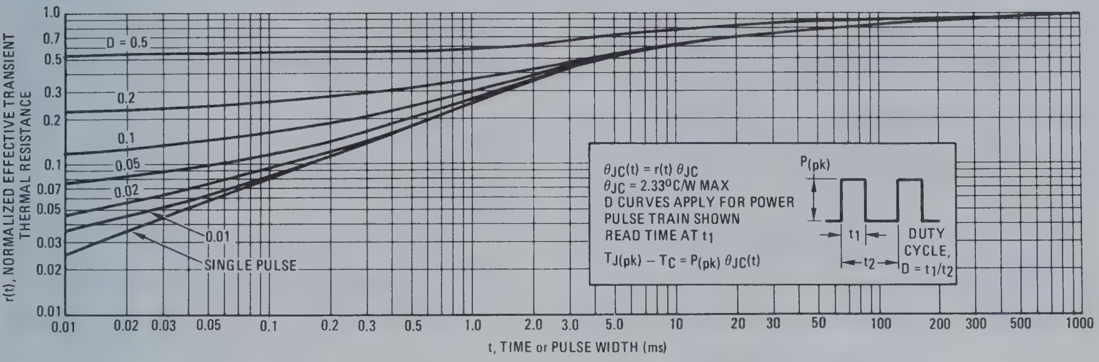
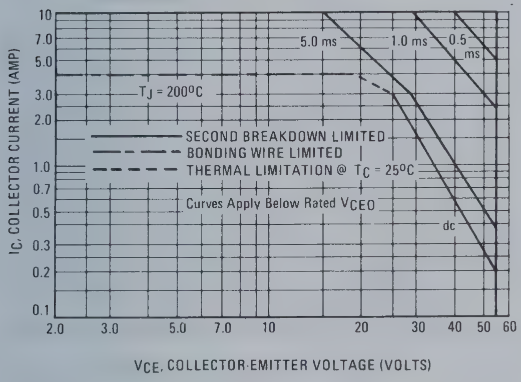


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200^{\circ}C$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} < 200^{\circ}C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415).

FIGURE 6 – TURN-OFF TIME

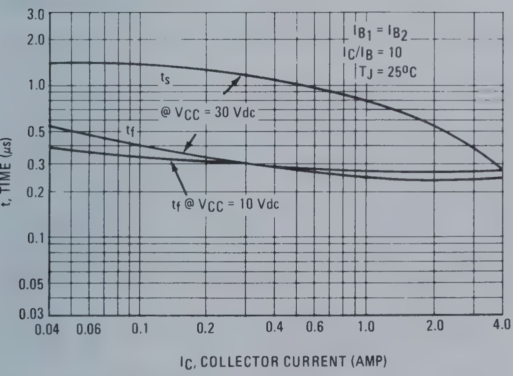


FIGURE 7 – CAPACITANCE

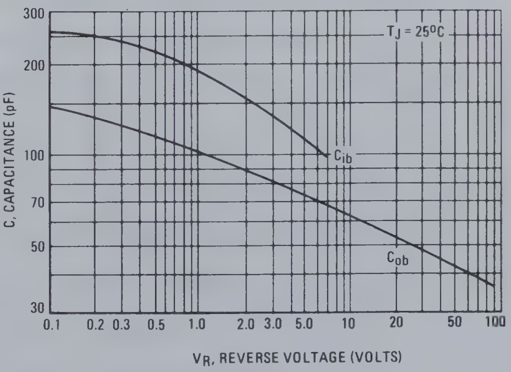


FIGURE 8 – DC CURRENT GAIN

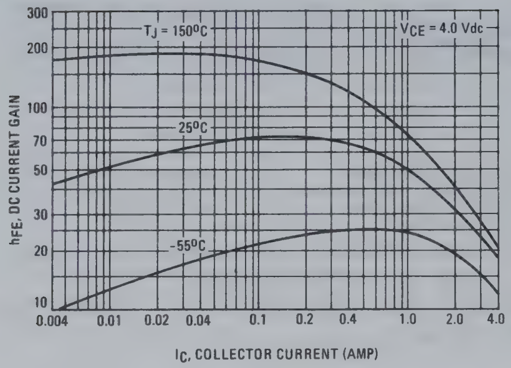


FIGURE 9 – COLLECTOR SATURATION REGION

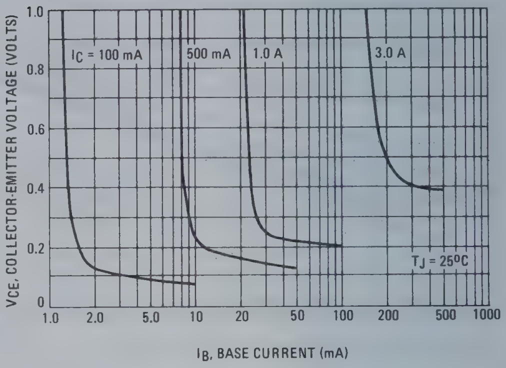


FIGURE 10 – TEMPERATURE COEFFICIENTS

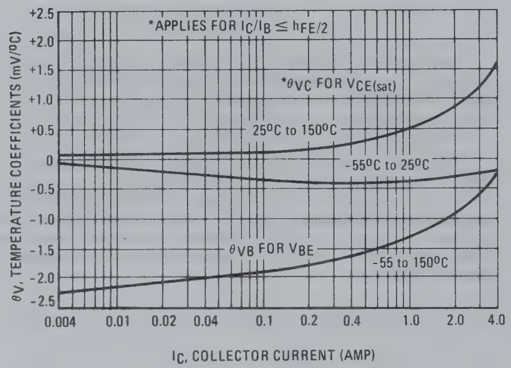


FIGURE 11 – "ON" VOLTAGES

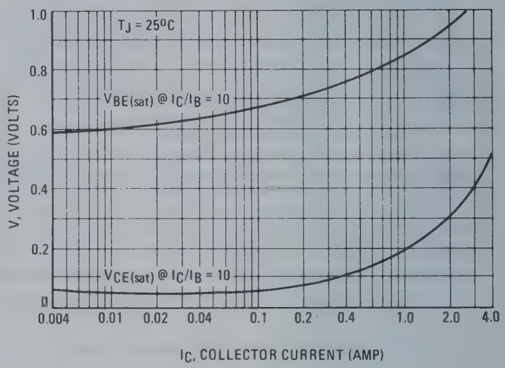


FIGURE 12 – COLLECTOR CUT-OFF REGION

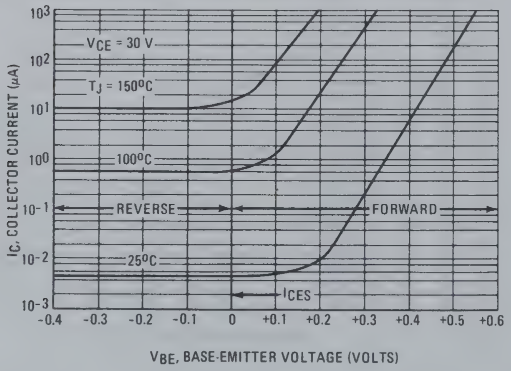
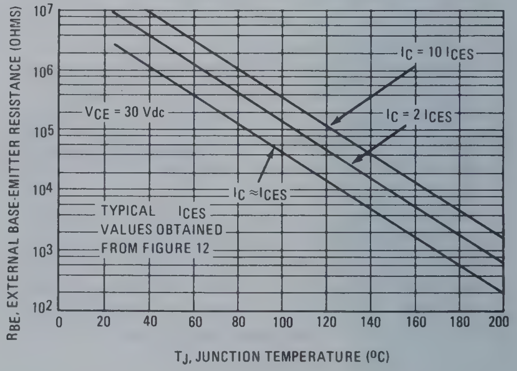


FIGURE 13 – EFFECTS OF BASE-EMITTER RESISTANCE



2N3055 (SILICON)

NPN SILICON POWER TRANSISTOR

. . . designed for general-purpose, moderate speed, switching and amplifier applications.

- DC Current Gain —
  h_{FE} = 20–70 @ I_C = 4.0 Adc
- Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 1.0 Vdc (Max) @ I_C = 4.0 Adc
- Excellent Safe Operating Area

*MAXIMUM RATINGS

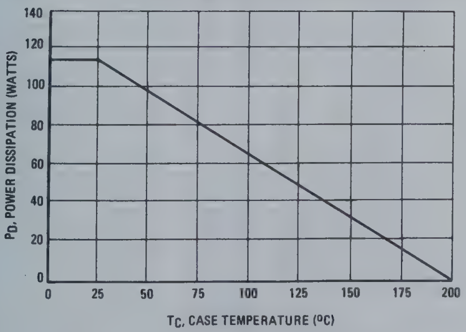
Rating	Symbol	Value	Unit
#Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage	V_{CER}	70	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current — Continuous	I_C	15	Adc
Base Current — Continuous	I_B	7.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	115 0.657	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.52	°C/W

*Indicates JEDEC Registered Data.
#Motorola guarantees this value in addition to JEDEC Registered Data.

FIGURE 1 — POWER TEMPERATURE DERATING CURVE

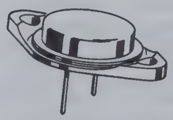


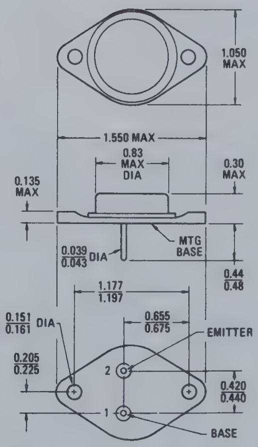
Safe Area Limits are indicated by Figure 9. Both limits are applicable and must be observed.

15 AMPERE
POWER TRANSISTOR

NPN SILICON

60 VOLTS
115 WATTS




1.050 MAX
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
MTG BASE
0.039/0.043 DIA
0.44/0.48
1.177/1.197
0.151/0.161 DIA
0.655/0.675
EMITTER
0.205/0.225
2
0.420/0.440
1
BASE

CASE 11
(TO-3)

Collector Connected to Case

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (Note 1) (I_C = 200 mAdc, I_B = 0)	$V_{CEO(sus)}$	60	–	Vdc
Collector-Emitter Breakdown Voltage (Note 1) (I_C = 200 mAdc, R_{BE} = 100 Ohms)	BV_{CER}	70	–	Vdc
Collector-Emitter Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	–	0.7	mAdc
Collector Cutoff Current (V_{CE} = 100 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 100 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	I_{CEX}	 – –	 5.0 30	mAdc
Emitter-Base Cutoff Current (V_{EB} = 7.0 Vdc, I_C = 0)	I_{EBO}	–	5.0	mAdc
ON CHARACTERISTICS				
DC Current Gain (Note 1) (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc) (I_C = 10 Adc, V_{CE} = 4.0 Vdc)	h_{FE}	 20 5.0	 70 –	–
Collector-Emitter Saturation Voltage (Note 1) (I_C = 4.0 Adc, I_B = 0.4 Adc) (I_C = 10 Adc, I_B = 3.3 Adc)	$V_{CE(sat)}$	 – –	 1.1 8.0	Vdc
Base-Emitter Voltage (Note 1) (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc)	V_{BE}	–	1.8	Vdc
DYNAMIC CHARACTERISTICS				
Small Signal Current Gain (Note 1) (V_{CE} = 4.0 Vdc, I_C = 1.0 Adc, f = 1.0 kHz)	h_{fe}	15	120	–
Small Signal Current Gain Cutoff Frequency (V_{CE} = 4.0 Vdc, I_C = 1.0 Adc, f = 1.0 kHz)	$f_{\alpha e}$	10	–	kHz

Note 1: Pulse Width ≈ 300 μs, Duty Cycle ≤ 2.0%.

*Indicates JEDEC Registered Data.

FIGURE 2 – BASE CURRENT-VOLTAGE VARIATIONS

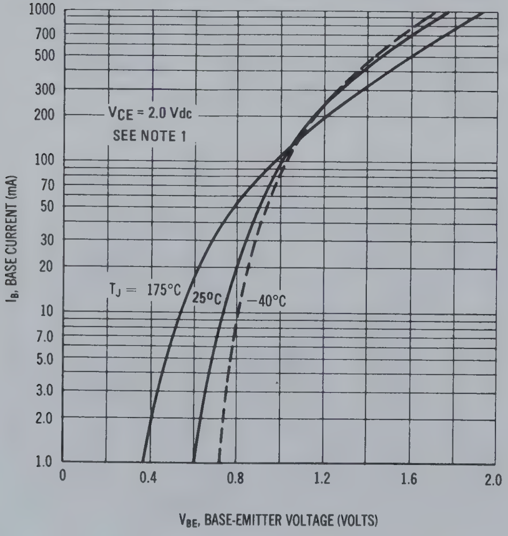
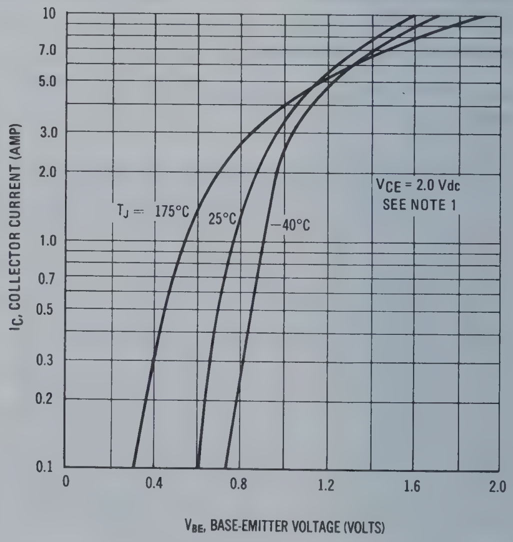


FIGURE 3 – COLLECTOR CURRENT-VOLTAGE VARIATIONS



Note 1. Pulse Test: Pulse Width ≈ 200 μs, Duty Cycle ≈ 1.5%.

FIGURE 4 – COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

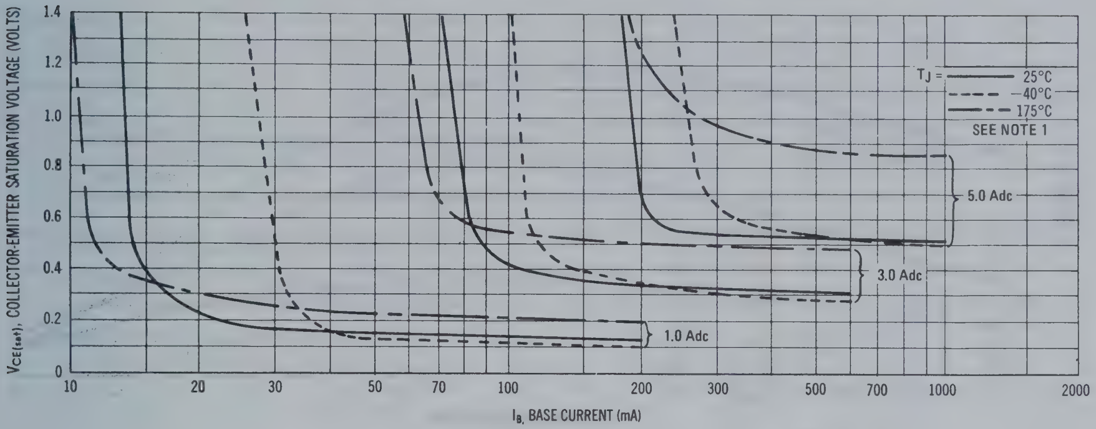


FIGURE 5 – BASE-EMITTER SATURATION VOLTAGE VARIATIONS

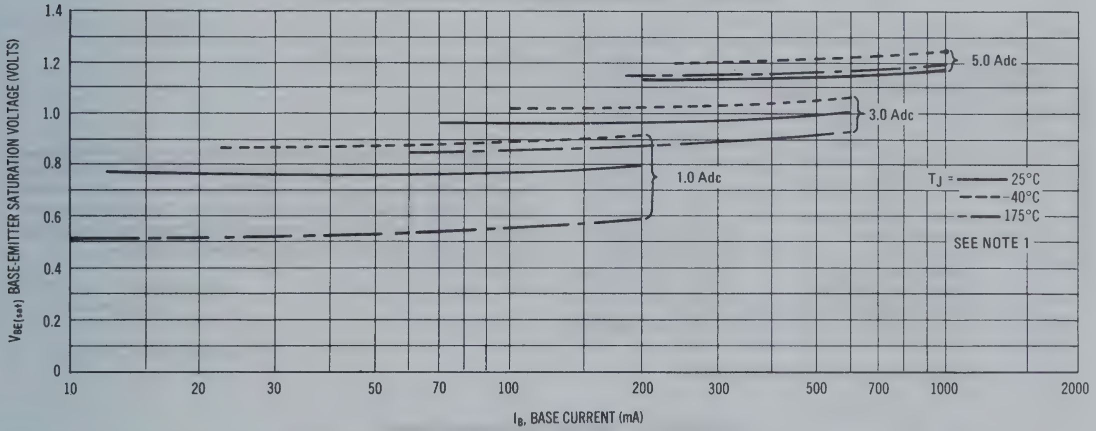


FIGURE 6 – COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

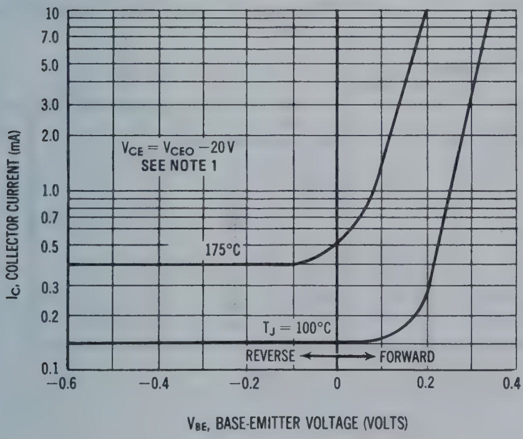


FIGURE 7 – COLLECTOR CURRENT versus BASE-EMITTER RESISTANCE

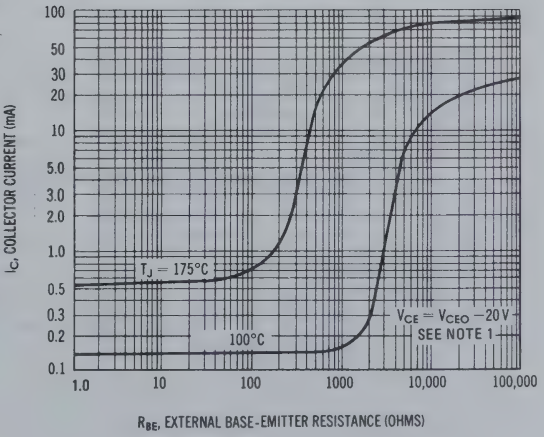


FIGURE 8 – CURRENT GAIN VARIATIONS

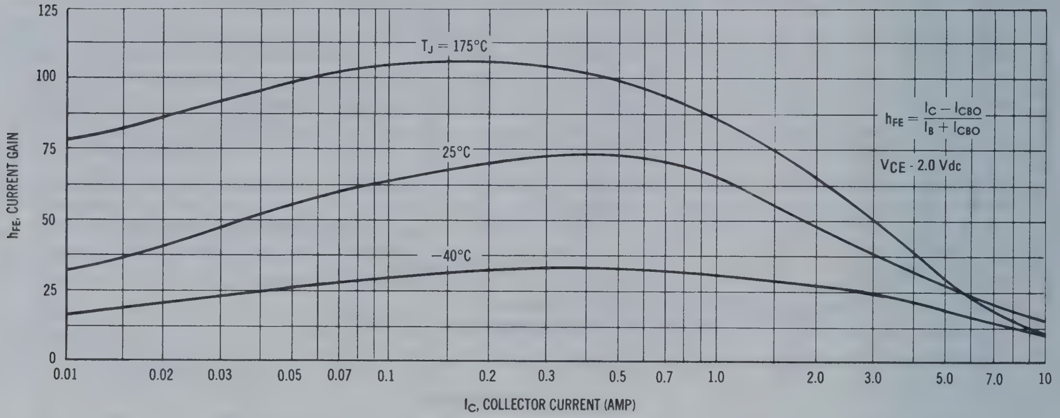
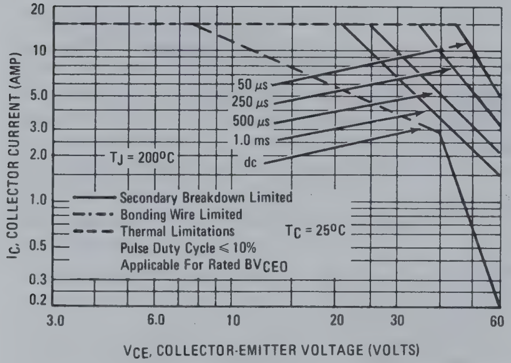
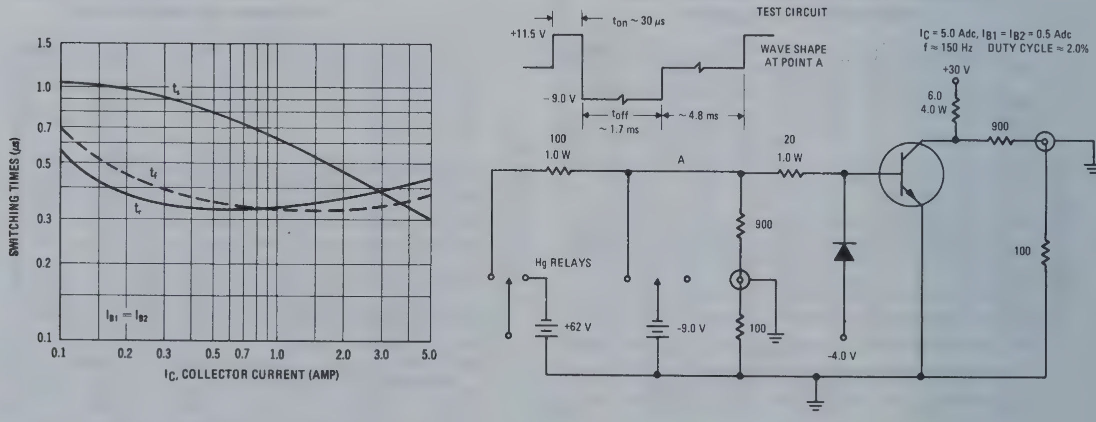


FIGURE 9 – ACTIVE-REGION SAFE OPERATING AREA



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

FIGURE 10 – TYPICAL SWITCHING TIMES



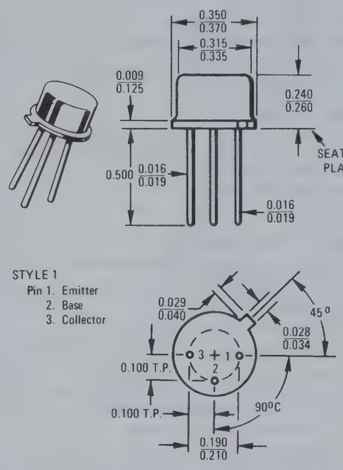
2N3072 (SILICON)
2N3073

PNP SILICON ANNULAR TRANSISTORS

. . . designed for medium-speed, industrial switching applications.

- Choice of Package and Power Ratings
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)} = 0.25$ Vdc (Max) @ $I_C = 50$ mAdc
- High Small-Signal Current Gain —
  $h_{fe} = 180$ (Max) @ $I_C = 10$ mAdc

PNP SILICON TRANSISTORS


0.350
0.370
0.315
0.335
0.009
0.125
0.240
0.260
SEATING PLANE
0.500
0.016
0.019
0.016
0.019
0.029
0.040
45°
0.028
0.034
0.100 T.P.
0.100 T.P.
3
1
2
90°C
0.190
0.210

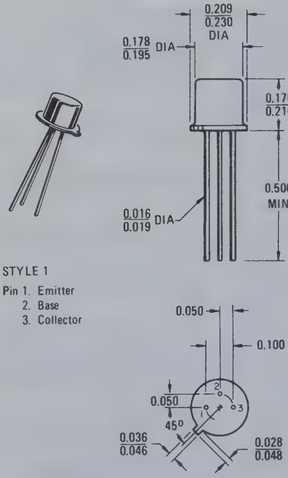
STYLE 1
Pin 1. Emitter
2. Base
3. Collector

2N3072 CASE 79(1)
TO-39

*MAXIMUM RATINGS

Rating	Symbol	2N3072	2N3073	Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current — Continuous	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	800 4.56	360 2.06	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	3.0 17.1	1.2 6.85	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−65 to +200		°C

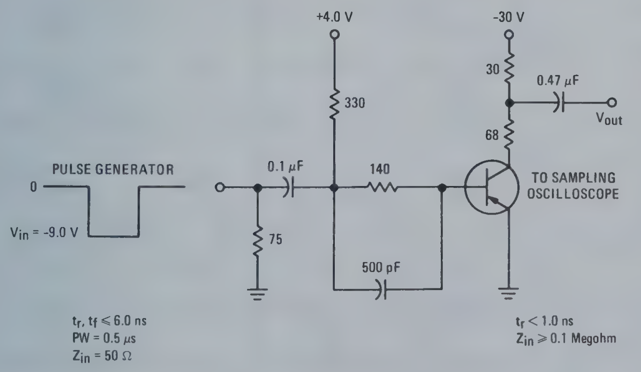
*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
2
1
3
45°
0.036
0.046
0.028
0.048

STYLE 1
Pin 1. Emitter
2. Base
3. Collector

Collector Connected to Case
2N3073 CASE 22(1)
TO-18

FIGURE 1 — TURN-ON AND TURN-OFF SWITCHING TIMES TEST CIRCUIT


+4.0 V
−30 V
30
0.47 μF
330
V_{out}
68
PULSE GENERATOR
0
0.1 μF
140
TO SAMPLING OSCILLOSCOPE
$V_{in} = -9.0$ V
75
500 pF
$t_r, t_f \leq 6.0$ ns
PW = 0.5 μs
$Z_{in} = 50\ \Omega$
$t_r < 1.0$ ns
$Z_{in} \geqslant 0.1$ Megohm

***ELECTRICAL CHARACTERISTICS** ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	60	–	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current	I_{CES}			
(V_{CE} = 30 Vdc, V_{BE} = 0)		–	10	nAdc
(V_{CE} = 30 Vdc, V_{BE} = 0, T_A = 125°C)		–	10	μAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	–	100	μAdc
Base Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_B	–	10	nAdc
ON CHARACTERISTICS				
DC Current Gain(1)	h_{FE}			–
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)		30	130	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)		12	–	
(I_C = 300 mAdc, V_{CE} = 2.0 Vdc)		15	–	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)		–	0.25	
(I_C = 300 mAdc, I_B = 30 mAdc)		–	1.0	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 2.5 mAdc)		–	1.2	
(I_C = 300 mAdc, I_B = 30 mAdc)		–	2.0	
Base-Emitter On Voltage (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	$V_{BE(on)}$	–	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	130	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	–	10	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	–	1.5	k ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	–	26	$X 10^{-4}$
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	180	–
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	–	1200	μmhos
SWITCHING CHARACTERISTICS (Figure 1)				
Turn-On Time ($I_C \approx 300$ mAdc, $I_{B1} \approx 30$ mAdc)	t_{on}	–	40	ns
Turn-Off Time ($I_C \approx 300$ mAdc, $I_{B1} \approx I_{B2} \approx 30$ mAdc)	t_{off}	–	100	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N3081 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for medium-speed switching and general-purpose amplification applications in industrial service.

- High Collector-Base Breakdown Voltage —
  BV_{CBO} = 70 Vdc (Min) @ I_C = 10 μAdc
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.3 Vdc (Max) @ I_C = 150 mAdc

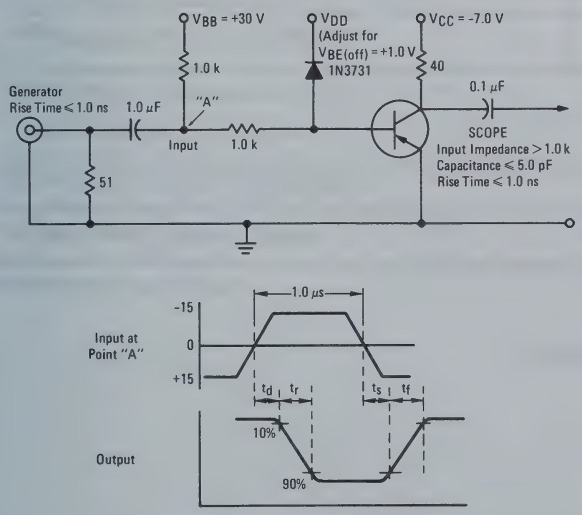
PNP SILICON TRANSISTOR

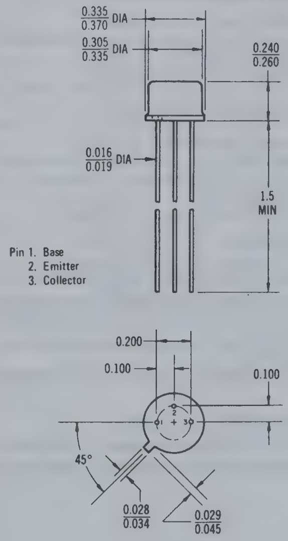
*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	70	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current — Continuous	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.6 3.4	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.0 11.5	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT


VBB = +30 V
VDD
(Adjust for
VBE(off) = +1.0 V)
VCC = -7.0 V
1.0 k
1N3731
40
0.1 µF
Generator
Rise Time ≤ 1.0 ns
1.0 µF
"A"
Input
1.0 k
SCOPE
Input Impedance > 1.0 k
Capacitance ≤ 5.0 pF
Rise Time ≤ 1.0 ns
51
1.0 µs
-15
0
+15
Input at
Point "A"
td
tr
ts
tf
10%
90%
Output


0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
0.016
0.019
DIA
1.5
MIN
Pin 1. Base
2. Emitter
3. Collector
0.200
0.100
0.100
45°
0.028
0.034
0.029
0.045

CASE 31 (1)
TO-5

Collector Connected to Case

To convert inches to millimeters multiply by 25.4.

*ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage ($I_C = 10$ mAdc, $I_B = 0$)	$V_{CEO(sus)}$	50	–	Vdc
Collector-Base Breakdown Voltage ($I_C = 10\ \mu$Adc, $I_E = 0$)	BV_{CBO}	70	–	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	6.0	–	Vdc
Collector Cutoff Current ($V_{CE} = 35$ Vdc, $V_{EB(off)} = 0.5$ Vdc)	I_{CEV}	–	10	nAdc
Collector Cutoff Current	I_{CBO}			
($V_{CB} = 50$ Vdc, $I_E = 0$)		–	10	nAdc
($V_{CB} = 50$ Vdc, $I_E = 0$, $T_A = 150^oC$)		–	10	μAdc
Emitter Cutoff Current ($V_{EB} = 5.0$ Vdc, $I_C = 0$)	I_{EBO}	–	100	nAdc
Base Current ($V_{CE} = 35$ Vdc, $V_{EB(off)} = 0.5$ Vdc)	I_B	–	10	nAdc
ON CHARACTERISTICS				
DC Current Gain(1)	h_{FE}			–
($I_C = 150$ mAdc, $V_{CE} = 0.6$ Vdc)		20	–	
($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc)		30	90	
($I_C = 500$ mAdc, $V_{CE} = 2.8$ Vdc)		15	–	
($I_C = 500$ mAdc, $V_{CE} = 10$ Vdc)		20	–	
Collector-Emitter Saturation Voltage(1)	$V_{CE(sat)}$			Vdc
($I_C = 150$ mAdc, $I_B = 15$ mAdc)		–	0.3	
($I_C = 500$ mAdc, $I_B = 50$ mAdc)		–	1.4	
Base-Emitter Voltage(1) ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	V_{BE}	–	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz)	f_T	150	–	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 1.0 MHz)	C_{ob}	–	13	pF
Input Capacitance ($V_{EB} = 0.5$ Vdc, $I_C = 0$, f = 1.0 MHz)	C_{ib}	–	70	pF
SWITCHING CHARACTERISTICS (See Figure 1)				
Turn-On Time	t_{on}	–	60	ns
Turn-Off Time	t_{off}	–	175	ns

*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Width $\leq 300\ \mu s$, Duty Cycle = 1.0%.

(2) f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N3114 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-voltage, low-power video amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	150	Vdc
Collector-Emitter Voltage*	V_{CEO}	150*	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	0.8 4.57	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Between 0 and 30 mA.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	150	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	150	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$*	—	1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{BE(sat)}$*	—	0.9	Vdc
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	h_{FE}*	 15 30 12	 — 120 —	—
Collector Cutoff Current (V_{CB} = 100 Vdc, I_E = 0) (V_{CB} = 100 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 — —	 0.010 10	μAdc
Emitter Cutoff Current (V_{EB} = 4 Vdc, I_C = 0)	I_{EBO}	—	0.10	μAdc
Small Signal Current Gain (V_{CE} = 10 Vdc, I_C = 30 mAdc, f = 20 MHz)	$\|h_{fe}\|$	2.0	—	—
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	9.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	80	pF
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 5 V, f = 1 kHz)	h_{fe}	25	—	—
Real Part of Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 100 MHz)	$Re(h_{ie})$	—	30	ohms

*PW ≤ 300 μsec, Duty Cycle ≤ 1%

2N3115 (SILICON)
2N3116

For Specifications, See 2N2958 Data

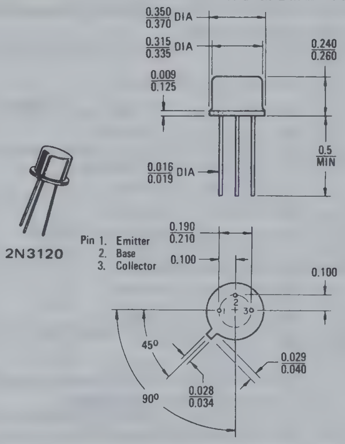
2N3120 (SILICON)
2N3121

PNP SILICON ANNULAR TRANSISTORS

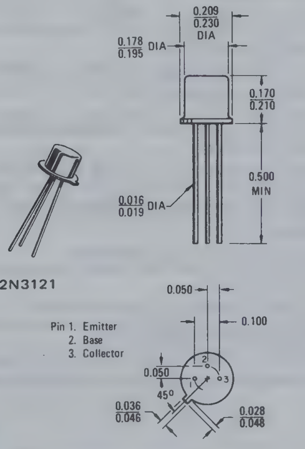
. . . designed for general-purpose, medium-speed switching applications.

- Choice of Package and Power Ratings
- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)} = 0.25$ Vdc (Max) @ $I_C = 50$ mAdc
- DC Current Gain Specified From 50 mAdc to 300 mAdc

PNP SILICON TRANSISTORS


0.350
0.370 DIA
0.315
0.335 DIA
0.240
0.260
0.009
0.125
0.5
MIN
0.016
0.019 DIA
2N3120
Pin 1. Emitter
2. Base
3. Collector
0.190
0.210
0.100
0.100
45°
90°
0.028
0.034
0.029
0.040
1
2
3

CASE 79
TO-39


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
2N3121
0.050
0.100
Pin 1. Emitter
2. Base
3. Collector
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

Collector Connected to Case
CASE 22(1)
TO-18

*MAXIMUM RATINGS

Rating	Symbol	2N3120	2N3121	Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current — Continuous	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	800 4.56	360 2.06	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.1	1.2 6.85	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*Indicates JEDEC Registered Data

*ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

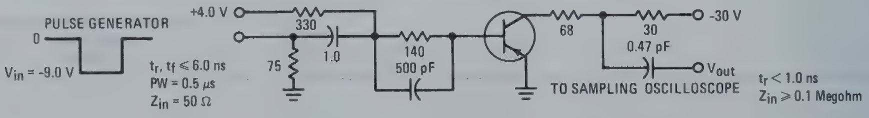
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	45	–	Vdc
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_E = 0)	BV_{CBO}	45	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)	BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) (V_{CE} = 30 Vdc, V_{BE} = 0, $T_A = 125^\circ C$)	I_{CES}	 – –	 10 10	 nAdc µAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	–	100	µAdc
Base Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_B	–	10	nAdc
ON CHARACTERISTICS				
DC Current Gain(1) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc, $T_A = -55^\circ C$) (I_C = 300 mAdc, V_{CE} = 2.0 Vdc)	h_{FE}	 30 12 15	 130 – –	–
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 2.5 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$	 – – –	 0.25 0.5 1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 2.5 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$	 – –	 1.2 2.0	Vdc
Base-Emitter On Voltage (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	$V_{BE(on)}$	–	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	130	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	–	10	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	–	1.5	k ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	–	26	$\times 10^{-4}$
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	180	–
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	–	1200	µmhos
SWITCHING CHARACTERISTICS (Figure 1)				
Turn-On Time ($I_C \approx 300$ mAdc, $I_{B1} \approx 30$ mAdc)	t_{on}	–	40	ns
Turn-Off Time ($I_C \approx 300$ mAdc, $I_{B1} = I_{B2} \approx 30$ mAdc)	t_{off}	–	100	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 µs, Duty Cycle = 1.0%.

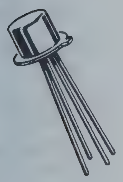
(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT



2N3127 (GERMANIUM)

2N3127 JAN AVAILABLE



CASE 20
(TO-72)

Active Elements Isolated From Case

PNP germanium mesa transistor designed for industrial and commercial VHF/UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	0.75	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	100 1.33	mW mW/^oC
Operating & Storage Junction Temperature	T_J, T_{stg}	-65 to + 100	^oC

TABLE I – GROUP A INSPECTION (T_A = 25°C unless otherwise noted) (LTPD applies to JAN 2N3127 only)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Visual and Mechanical Examination	2071	—	—	—	—	10
SUBGROUP 2						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	3001 Condition D	BV_{CBO}	25	—	Vdc	5
Collector-Emitter Breakdown Voltage (I_C = 2 mAdc, I_B = 0)	3011 Condition D	BV_{CEO}	20	—	Vdc	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	3011 Condition C	BV_{CES}	25	—	Vdc	
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	3.0	μAdc	
Emitter-Base Cutoff Current (V_{BE} = 0.75 Vdc, I_C = 0)	3061 Condition D	I_{EBO}	—	100	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
Base-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 1 mAdc)	3066 Condition A	$V_{BE(sat)}$	—	0.6	Vdc	
Collector-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 1 mAdc)	3071	$V_{CE(sat)}$	—	0.3	Vdc	
SUBGROUP 3						
Small-Signal Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	3206	h_{fe}	20	125	—	10
Current-Gain — Bandwidth Product (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 100 MHz)	3261	f_T	400	—	MHz	
Collector - Base Capacitance* (V_{CB} = 10 Vdc, I_E = 0, f $\geq$ 0.1 $\leq$ 1.0 MHz)	3236	C_{cb}*	—	1.2	pF	
SUBGROUP 4						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0, T_A = 85°C)	3036 Condition D	I_{CBO}	—	50	μAdc	10
DC Current Gain ‡ (I_C = 3 mAdc, V_{CE} = 10 Vdc, T_A = -55^{+0}_{-3} °C)	3076	h_{FE}‡	7.0	—	—	
SUBGROUP 5						
Power Gain (Figure 1) (I_C = 3 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz)	3256	G_{pe}	17	25	dB	15
Noise Figure (Figure 1) (I_C = 3 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz)	3246	NF	—	5.0	dB	

STANDARD UNIT ONLY

Collector-Base Time Constant (Figure 2) (I_C = 3 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	r'_bC_c	1.0	12	ps	—

* Measured in a guarded circuit, such that the can capacitance is not included.

‡ Applies to JAN unit only.

2N3127 (continued)

TABLE II – GROUP B INSPECTION – JAN 2N3127 only (T_A = 25°C unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Physical Dimensions	2066	—	—	—	—	20
SUBGROUP 2						
Solderability (Omit aging)	2026	—	—	—	—	15
Temperature Cycling (T_{high} = 100 $^{+3}_{-0}$ °C)	1051 Condition B	—	—	—	—	
Thermal Shock (Glass Strain)	1056 Condition A	—	—	—	—	
Seal (Leak Rate)**	** Condition C, Procedure IIIa. Condition B for Gross Leaks	—	—	10^{-7}	atm cc/s	
Moisture Resistance	1021	—	—	—	—	
End-Point Tests: (Subgroups 2, 3)						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc)	3036 Condition D	I_{CBO}	—	3.0	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
SUBGROUP 3						
Shock (Non-operating; 1500 G; 5 blows of 0.5 ms each in Orientations X_1, Y_1, Y_2, and Z_1) (total = 20 blows)	2016	—	—	—	—	15
Vibration Fatigue (Non-operating; 20G)	2046	—	—	—	—	
Vibration, Variable Frequency	2056	—	—	—	—	
Constant Acceleration (Centrifugal) (20,000G, Orientations X_1, Y_1, Y_2, and Z_1)	2006	—	—	—	—	
End-Point Tests: Same as Subgroup 2						
SUBGROUP 4						
Lead Fatigue	2036 Condition E	—	—	—	—	15
SUBGROUP 5						
High-Temperature Life (Non-operating) (T_{stg} = 100°C)	1031	—	—	—	—	λ = 15
End-Point Tests: (Subgroups 5, 6)						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	6.0	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	17	125	—	
SUBGROUP 6						
Steady State Operation Life (I_C = 10 mAdc, V_{CB} = 10 Vdc)	1026	—	—	—	—	λ = 15
End-Point Tests: Same as Subgroup 5						

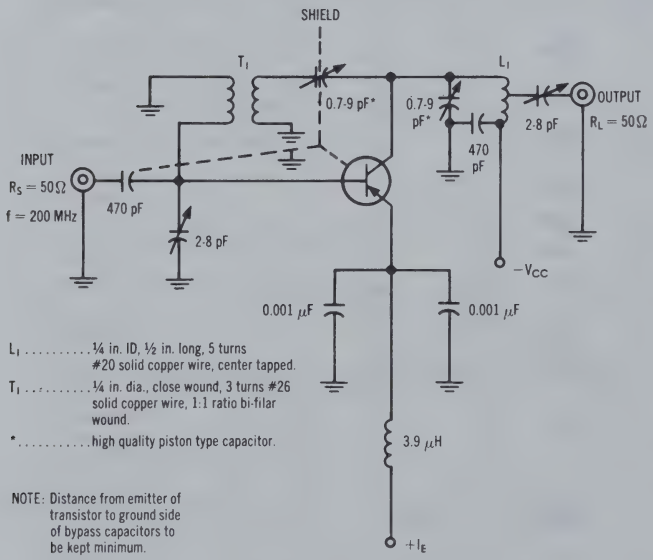
**Per Method 112 of MIL-STD-202

TABLE III – GROUP C INSPECTION‡ – JAN 2N3127 only (T$_A$ = 25°C unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Collector-Base Time Constant (Figure 2) (I_C = 3 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)		$r_b'C_c$	—	12	ps	20
Salt Atmosphere (Corrosion)	1041	—	—	—	—	
End-Point Tests:						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	3.0	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
SUBGROUP 2						
Output Conductance (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 30 MHz)	3216	$Re(h_{oe})$	1.0	3.5	mmhos	10
Input Conductance (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 30 MHz)	3221	$Re(y_{ie})$	1.25	5.0	mmhos	

‡ Group C tests shall be performed on the initial lot and every six months thereafter.

FIGURE 1 — TEST CIRCUIT FOR POWER GAIN AND NOISE FIGURE


SHIELD
T₁
L₁
0.7-9 pF*
0.7-9 pF*
470 pF
2-8 pF
OUTPUT
R$_L$ = 50Ω
INPUT
R$_S$ = 50Ω
f = 200 MHz
470 pF
2-8 pF
−V$_{CC}$
0.001 μF
0.001 μF
3.9 μH
+I$_E$

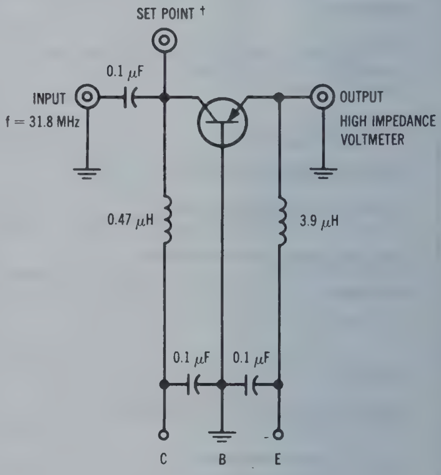
L₁ . . . . ¼ in. ID, ½ in. long, 5 turns #20 solid copper wire, center tapped.

T₁ . . . . ¼ in. dia., close wound, 3 turns #26 solid copper wire, 1:1 ratio bi-filar wound.

* . . . . high quality piston type capacitor.

NOTE: Distance from emitter of transistor to ground side of bypass capacitors to be kept minimum.

FIGURE 2 — TEST CIRCUIT FOR COLLECTOR-BASE TIME CONSTANT


SET POINT †
0.1 μF
INPUT
f = 31.8 MHz
OUTPUT
HIGH IMPEDANCE VOLTMETER
0.47 μH
3.9 μH
0.1 μF
0.1 μF
C
B
E

† NOTE: E_{in} = 0.5 V measured at set point.
$r_b'C_c$ = E_{out} (in mV) × 10

2N3133 thru 2N3136 (SILICON)

CASE 31
(TO-5)

2N3133
2N3134

CASE 22
(TO-18)

2N3135
2N3136

Collector connected to case

PNP silicon annular Star transistors for high-speed switching and DC to UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3133 2N3134 (TO-5)	2N3135 2N3136 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	50	50	Vdc
Collector-Emitter Voltage	V_{CEO}	35	35	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	Vdc
Collector Current	I_C	600	600	mA
Total Device Dissipation @25°C Case Temperature Derate Above 25°C	P_D	3 17.3	1.8 10.3	Watts mW/°C
Total Device Dissipation @25°C Ambient Temperature Derate Above 25°C	P_D	0.6 3.43	0.4 2.28	Watts mW/°C
Junction Temperature	T_J	-65 to +200		°C
Storage Temperature	T_{stg}	-65 to +200		°C

SWITCHING CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Typ	Max	Unit
Turn-On Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_{on}	26	75	ns
Turn-Off Time (V_{CC} = 6V, I_{CS} = 150 mA, I_{B1} = I_{B2} = 15 mA)	t_{off}	70	150	ns

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	--- ---	0.05 30	µAdc
Collector Cutoff Current (V_{CE} = 30 V, V_{BE} = 0.5 V)		I_{CEX}	---	0.1	µAdc
Base Cutoff Current (V_{CE} = 30 V, V_{BE} = 0.5 V)		I_{BL}	---	0.1	µAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)		BV_{CBO}	50	---	Vdc
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	35	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	4.0	---	Vdc
Collector Saturation Voltage [1] (I_C = 150 mAdc, I_B = 15 mAdc)		V_{CE} (sat)	---	0.6	Vdc
Base-Emitter Saturation Voltage [1] (I_C = 150 mAdc, I_B = 15 mAdc)		V_{BE} (sat)	---	1.5	Vdc
DC Forward Current Transfer Ratio		h_{FE}			---
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N3133, 2N3135		25	---	
	2N3134, 2N3136		50	---	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) [1]	2N3133, 2N3135		40	120	
	2N3134, 2N3136		100	300	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	---	10	pF
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	---	40	pF
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	200	---	MHz

[1] Pulse Test: Pulse Width ≤ 300 µs, duty cycle ≤ 2%

2N3137 (SILICON)
MM1803

CASE 31
(TO-5)

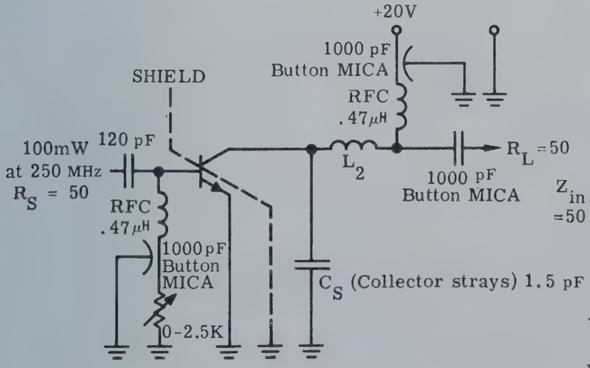
Collector connected to case

NPN silicon annular transistors for large signal VHF and UHF applications.

MAXIMUM RATINGS

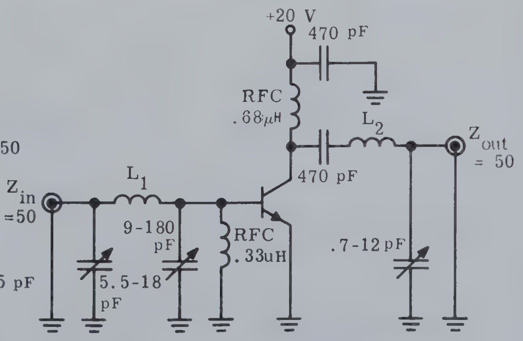
Rating	Symbol	2N3137	MM1803	Units
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	20	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0	5.0	Vdc
Collector Current (Continuous)	I_C	150	150	mAdc
Power Dissipation @25° C Case Temperature @25° C Ambient Temperature	P_D	 2.0 0.8		Watts
Operating Junction Temperature Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C
Thermal Resistance Junction to Case	θ_{JC}	87.5		°C/ Watt
Thermal Resistance Junction to Ambient	θ_{JA}	153		°C/ Watt

250 MHz POWER GAIN TEST CIRCUIT (2N3137)


+20V
1000 pF
Button MICA
SHIELD
RFC
.47µH
100mW
at 250 MHz
R_S = 50
120 pF
L_2
R_L = 50
1000 pF
Button MICA
RFC
.47µH
1000pF
Button
MICA
0-2.5K
C_S (Collector strays) 1.5 pF

L_2 = .075 µH (5.5 turns #16ga. ID = 3/16" length 1/2")

250 MHz POWER GAIN TEST CIRCUIT (MM1803)


+20 V
470 pF
RFC
.68µH
L_2
Z_out
= 50
470 pF
L_1
Z_in
=50
9-180
pF
RFC
.33uH
.7-12 pF
5.5-18
pF

L_1 = 3/4 turn No. 14 tinned wire 3/8" ID
L_2 = 4 turns No. 18 tinned wire 1/4" ID 7/16" long

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Typical	Max	Unit
Collector-Base Breakdown Voltage $I_C = 0.1$mAdc, $I_E = 0$ 2N3137 MM1803	V_{CBO}	40 50			Vdc
Collector-Emitter Open Base Sus. Voltage $I_C = 15$mAdc, $I_B = 0$ 2N3137 MM1803	$V_{CEO(sus)}$	20 25			Vdc
Collector Cutoff Current $V_{CB} = 20$Vdc, $I_E = 0$, $T_C = +150^\circ C$	I_{CBO}			50	μAdc
Collector Cutoff Current $V_{CB} = 20$Vdc, $I_E = 0$	I_{CBO}			.05	μAdc
Emitter-Base Breakdown Voltage $I_E = 100\mu A$, $I_C = 0$ 2N3137 MM1803	V_{EBO}	4.0 5.0			Vdc
DC Current Gain $V_{CE} = 5$Vdc, $I_C = 50$mAdc 2N3137 MM1803	h_{FE}	20 40		120 160	
Collector-Emitter Saturation Voltage $I_C = 50$mAdc, $I_E = 5$mAdc	$V_{CE(sat)}$			0.3	Vdc
Small Signal Current Gain $V_{CE} = 10$Vdc, $I_C = 50$mAdc, f = 100 MHz	$\|h_{fe}\|$	5.0			
Common-base Output Capacitance $V_{CB} = 10$Vdc, $I_C = 0$, f = 100 kHz	C_{ob}			3.5	pF
Power Output	P_{out}	400	600		mWatts
Power Gain $P_{in} = 100$mw, f = 250 MHz 2N3137	G_e	6.0	7.7		dB
Efficiency $V_{CE} = 20$Vdc	η	40	65		%
Power Output	P_{out}	560	700		mWatts
Power Gain $P_{in} = 100$mw, f = 250 MHz MM1803	G_e	7.5	8.5		db
Efficiency $V_{CE} = 20$V	η	45	60		%

*Pulse Width ≈ 300 μs, Duty cycle = 1%

2N3209 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for medium-speed saturated switching applications.

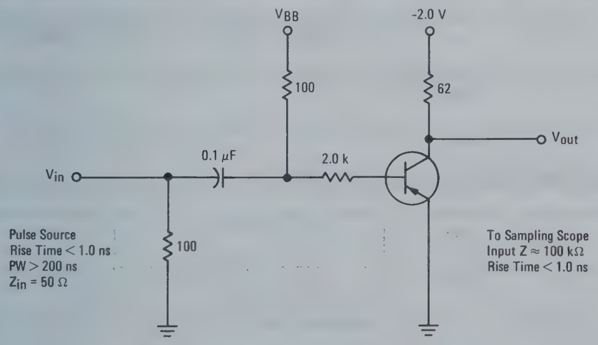
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.15 Vdc (Max) @ I_C = 10 mAdc
- Low Output Capacitance —
  C_{ob} = 5.0 pF (Max) @ V_{CB} = 5.0 Vdc
- DC Current Gain Specified — 10 mAdc to 100 mAdc

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.06	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.85	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

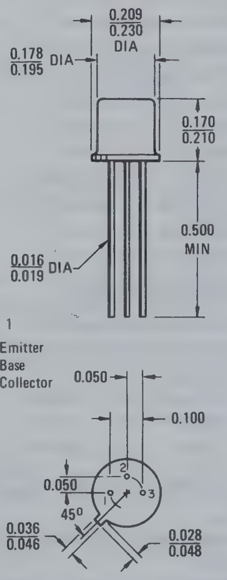
*Indicates JEDEC Registered Data.

FIGURE 1 — SWITCHING TIME TEST CIRCUIT


VBB
-2.0 V
100
62
Vout
0.1 μF
2.0 k
Vin
100
Pulse Source
Rise Time < 1.0 ns
PW > 200 ns
Zin = 50 Ω
To Sampling Scope
Input Z ≈ 100 kΩ
Rise Time < 1.0 ns

Notes:
(1) Collector Current ≈ 30 mA
(2) Turn On and Turn Off Base Currents ≈ 1.5 mA
(3) t_{on} – V_{BB} = +3.0 V, V_{in} = -7.0 V
(4) t_{off} – V_{BB} = -4.0 V, V_{in} = +6.0 V

PNP SILICON TRANSISTOR


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

STYLE 1
Pin 1. Emitter
2. Base
3. Collector

To convert to millimeters multiply by 25.4.
All JEDEC TO-18 dimensions and notes apply.

Collector Connected to Case
CASE 22(1)
TO-18

***ELECTRICAL CHARACTERISTICS** ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage(1) ($I_C = 10$ mAdc, $I_B = 0$)	$V_{CEO(sus)}$	20	–	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 10\ \mu$Adc, $V_{BE} = 0$)	BV_{CES}	20	–	Vdc
Collector-Base Breakdown Voltage ($I_C = 10\ \mu$Adc, $I_E = 0$)	BV_{CBO}	20	–	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current	I_{CES}			
($V_{CE} = 10$ Vdc, $V_{BE} = 0$)		–	0.080	μAdc
($V_{CE} = 10$ Vdc, $V_{BE} = 0$, $T_A = 125^{\circ}C$)		–	10	μAdc
Base Current ($V_{CE} = 10$ Vdc, $V_{BE} = 0$)	I_B	–	80	nAdc
ON CHARACTERISTICS				
DC Current Gain(1)	h_{FE}			–
($I_C = 10$ mAdc, $V_{CE} = 0.3$ Vdc)		25	–	
($I_C = 30$ mAdc, $V_{CE} = 0.5$ Vdc)		30	120	
($I_C = 30$ mAdc, $V_{CE} = 0.5$ Vdc, $T_A = -55^{\circ}C$)		12	–	
($I_C = 100$ mAdc, $V_{CE} = 1.0$ Vdc)		15	–	
Collector-Emitter Saturation Voltage(1)	$V_{CE(sat)}$			Vdc
($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)		–	0.15	
($I_C = 30$ mAdc, $I_B = 3.0$ mAdc)		–	0.2	
($I_C = 100$ mAdc, $I_B = 10$ mAdc)		–	0.6	
Base-Emitter Saturation Voltage(1)	$V_{BE(sat)}$			Vdc
($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)		0.78	0.98	
($I_C = 30$ mAdc, $I_B = 3.0$ mAdc)		0.85	1.2	
($I_C = 100$ mAdc, $I_B = 10$ mAdc)		–	1.7	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product(2) ($I_C = 30$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz)	f_T	400	–	MHz
Output Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 140 kHz)	C_{ob}	–	5.0	pF
Input Capacitance ($V_{EB} = 0.5$ Vdc, $I_C = 0$, f = 140 kHz)	C_{ib}	–	6.0	pF
SWITCHING CHARACTERISTICS (Figure 1)				
Turn-On Time ($I_C \approx 30$ mAdc, $I_{B1} \approx 1.5$ mAdc)	t_{on}	–	60	ns
Turn-Off Time ($I_C \approx 30$ mAdc, $I_{B1} = I_{B2} \approx 1.5$ mAdc)	t_{off}	–	90	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N3210 (SILICON)

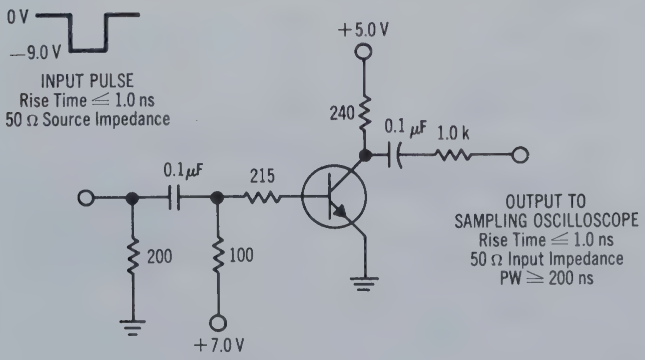
CASE 22
(TO-18)

NPN silicon high frequency switching transistor is designed for high speed, saturated switching applications for industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage Applicable from 0 to 500 mAdc	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT

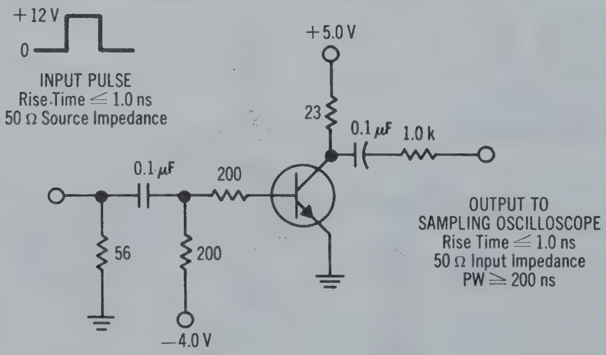

0 V
−9.0 V
INPUT PULSE
Rise Time ≦ 1.0 ns
50 Ω Source Impedance
+5.0 V
240
0.1 μF
1.0 k
0.1 μF
215
200
100
+7.0 V
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≦ 1.0 ns
50 Ω Input Impedance
PW ≧ 200 ns

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 2.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	-	25	nAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.010 15	μAdc
Emitter Cutoff Current (V_{EB} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{BL}	-	0.025	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	120	-
Collector-Emitter Saturation Voltage (I_C = 20 mAdc, I_B = 2.0 mAdc, T_A = +125°C) (I_C = 200 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	- -	0.25 0.75	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 200 mAdc, I_B = 20 mAdc)	$V_{BE(sat)}$	0.7 -	0.8 1.5	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	6.0	pF
Turn-On Time ($V_{BE(off)}$ ≧ 0.2 Vdc, I_C = 200 mAdc, I_{B1} = 40 mAdc) (Figure 2)	t_{on}	-	40	ns
Turn-Off Time (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc) (Figure 2)	t_{off}	-	40	ns
Storage Time ($I_C \approx I_{B1} \approx I_{B2} \approx$ 20 mAdc) (Figure 1)	t_s	-	20	ns

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

FIGURE 2 — TURN-ON AND TURN-OFF TEST CIRCUIT


+12 V
0
INPUT PULSE
Rise Time ≦ 1.0 ns
50 Ω Source Impedance
+5.0 V
23
0.1 μF
1.0 k
0.1 μF
200
56
200
−4.0 V
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≦ 1.0 ns
50 Ω Input Impedance
PW ≧ 200 ns

2N3211 (SILICON)

CASE 22
(TO-18)

NPN silicon high frequency switching transistor designed for high speed, saturated switching applications for industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

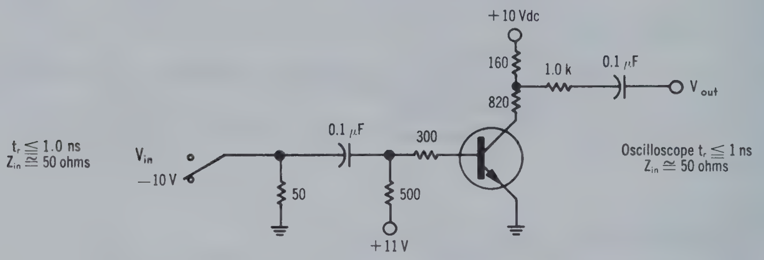
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	-	25	nAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc) (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc, T_A = 85°C)	I_{BL}	- -	0.025 10	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 100 μAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}	20 50 50 20 40 30 10	- - 150 - - - -	-
Collector-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	- - -	0.2 0.3 0.4	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	- - -	0.85 1.0 1.2	Vdc

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

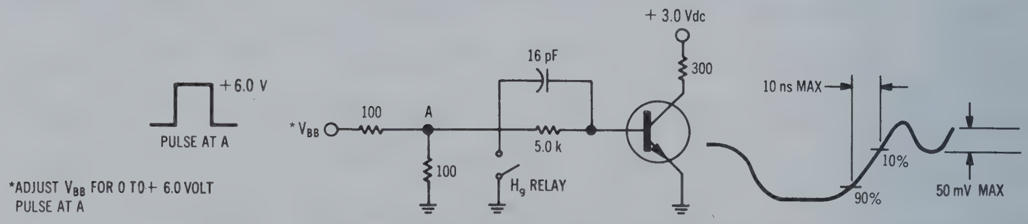
Characteristic	Symbol	Min	Max	Unit
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	7.0	pF
Charge-Storage Time Constant ($I_C \approx I_{B1} \approx I_{B2} \approx$ 10 mAdc) (Figure 1)	τ_s	-	15	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1.0 mAdc) (Figure 2)	Q_T	-	60	pC
Active Region Time Constant (I_C = 10 mAdc, I_B = 1.0 mAdc) (Figure 3)	τ_A	-	2.5	ns

FIGURE 1 — CHARGE STORAGE TIME CONSTANT TEST CIRCUIT



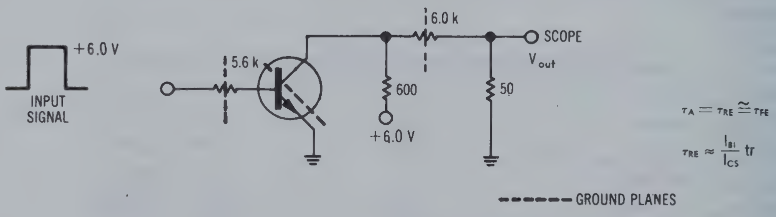
+10 Vdc
160
820
1.0 k
0.1 μF
V out
tr ≦ 1.0 ns
Zin ≅ 50 ohms
Vin
−10 V
0.1 μF
300
50
500
+11 V
Oscilloscope tr ≦ 1 ns
Zin ≅ 50 ohms

FIGURE 2 — TOTAL CONTROL CHARGE TEST CIRCUIT



+ 3.0 Vdc
300
16 pF
+6.0 V
PULSE AT A
*VBB
100
A
100
5.0 k
Hg RELAY
10 ns MAX
10%
90%
50 mV MAX
*ADJUST VBB FOR 0 TO + 6.0 VOLT PULSE AT A

FIGURE 3 — ACTIVE REGION TIME CONSTANT TEST CIRCUIT



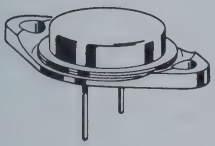
+6.0 V
INPUT SIGNAL
5.6 k
6.0 k
SCOPE
Vout
600
+6.0 V
50
τA = τRE ≅ τFE
τRE ≈ IB1/ICS tr
------ GROUND PLANES

NOTES FOR FIGURES 2, 3

INPUT PULSE — TRANSITION TIME TO +6.0 Vdc ≦ 2.0 ns
INPUT PULSE — OPTIONAL GENERATOR OUTPUT IMPEDANCE: ADJUST FOR + 6.0 Vdc
SCOPE INPUT CAPACITANCE = 3.0 pF MAX
SCOPE INPUT IMPEDANCE = 10 MEGOHMS
SCOPE RISE TIME ≦ 0.7 ns

2N3227 (SILICON) For Specifications, See 2N2369 Data.

2N3232 (SILICON)
2N3235



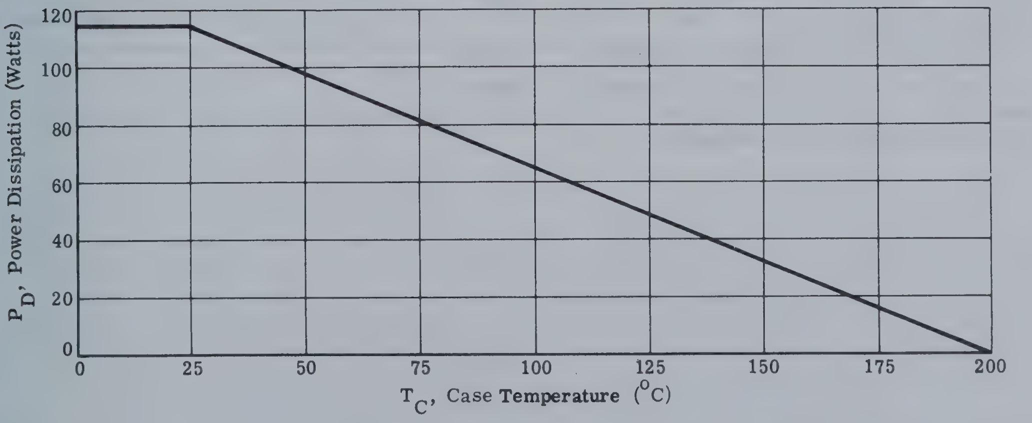
CASE 11
(TO-3)

NPN silicon power transistors designed for switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3232	2N3235	Units
Collector-Base Voltage	V_{CB}	60	55	Vdc
Collector-Emitter Voltage	V_{CEO}	60	55	Vdc
Emitter-Base Voltage	V_{EB}	6.0	7.0	Vdc
Collector Current (Continuous)	I_C	7.5	15	Adc
Base Current (Continuous)	I_B	3.0	7.0	Adc
Power Dissipation	P_D	117		Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5		°C/W
Junction Operating Temperature Range	T_J	-65 to +200		°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 6.0 Vdc)	2N3232		-	1.0	
(V_{EB} = 7.0 Vdc)	2N3235		-	5.0	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc)	2N3232 2N3235		- -	1.0 1.0	
(V_{CE} = 30 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3232 2N3235		- -	5.0 5.0	
Collector-Emitter Sustaining Voltage*		$V_{CEO(sus)}$*			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3232 2N3235		60 55	- -	
Collector Current		I_{CEO}			mAdc
(V_{CE} = 60 Vdc, I_B = 0)	2N3232		-	10	
(V_{CE} = 55 Vdc, I_B = 0)	2N3235		-	10	
DC Current Gain*		h_{FE}			-
(I_C = 1.5 Adc, V_{CE} = 10 Vdc)	2N3232		18	-	
(I_C = 3.0 Adc, V_{CE} = 10 Vdc)	2N3232		18	55	
(I_C = 2 Adc, V_{CE} = 4 Vdc)	2N3235		20	-	
(I_C = 4 Adc, V_{CE} = 4 Vdc)	2N3235		20	70	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 0.2 Adc)	2N3232		-	2.5	
(I_C = 4.0 Adc, I_B = 0.4 Adc)	2N3235		-	1.1	
Base-Emitter Voltage*		V_{BE}			Vdc
(I_C = 3.0 Adc, V_{CE} = 10 Vdc)	2N3232		-	3.5	
(I_C = 4.0 Adc, V_{CE} = 4 Vdc)	2N3235		-	1.8	
Small Signal Current Gain		h_{fe}			-
(V_{CE} = 10 Vdc, I_C = 3.0 Adc, f = 1.0 MHz)	2N3232		1.0	-	
(V_{CE} = 4 Vdc, I_C = 4.0 Adc, f = 1.0 MHz)	2N3235		1.0	-	

*Use sweep test to prevent overheating.

2N3244 (SILICON)
2N3245

CASE 31
(TO-5)

Collector connected to case

PNP silicon annular transistors for medium-current, high-speed switching and driver applications.

MAXIMUM RATINGS

Rating	Symbol	2N 3244	2N 3245	Unit
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ 25° C Ambient Temperature Derating Factor Above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ 25 ° C Case Temperature Derating Factor Above 25°C	P_D	5.0 28.6		Watts mW/°C
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
Thermal Resistance, Junction to Ambient Thermal Resistance, Junction to Case	θJA θJC	0.175 35		°C/mW °C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 100°C)		I_{CBO}	— —	.050 10	μAdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{CEX}	—	50	nAdc
Emitter-Base Leakage Current (V_{EB} = 3 Vdc, I_C = 0)		I_{EBO}	—	30	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{BL}	—	80	nAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0) 2N3244 2N3245		BV_{CBO}	40 50	— —	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0) 2N3244 2N3245		BV_{CEO}	40 50	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10μ Adc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc) 2N3244 2N3245 (I_C = 500 mAdc, I_B = 50 mAdc) 2N3244 2N3245 (I_C = 1 Adc, I_B = 100 mAdc) 2N3244 2N3245	2,3	$V_{CE(sat)}$	— — — — — —	0.3 0.35 0.5 0.6 1.0 1.2	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)	3	$V_{BE(sat)}$	— 0.75 —	1.1 1.5 2.0	Vdc
DC Forward Current Transfer Ratio (1) (I_C = 150 mAdc, V_{CE} = 1.0 Vdc) 2N3244 2N3245 (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) 2N3244 2N3245 (I_C = 1 Adc, V_{CE} = 5 Vdc) 2N3244 2N3245	1	h_{FE}	60 35 50 30 25 20	— — 150 90 — —	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	5	C_{ob}	—	25	pF
Input Capacitance (V_{OB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	5	C_{ib}	—	100	pF
Current-Gain - Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N3244 2N3245		f_T	175 150	— —	MHz
Delay Time (I_C = 500 mA, I_{B1} = 50 mA V_{OB} = 2 V, V_{CC} = 30 V)	6,8	t_d	—	15	ns
Rise Time 2N3244 2N3245		t_r	— —	35 40	ns
Storage Time (I_C = 500 mA, V_{CC} = 30 V I_{B1} = I_{B2} = 50 mA) 2N3244 2N3245	6,9	t_s	—	140 120	ns
Fall Time		t_f	—	45	ns
Total Control Charge (I_C = 500 mA, I_B = 50 mA, V_{CC} = 30 V) 2N3244 2N3245	7,10	Q_T	— —	14 12	nC

(1) Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

FIGURE 1 — MINIMUM CURRENT GAIN CHARACTERISTICS

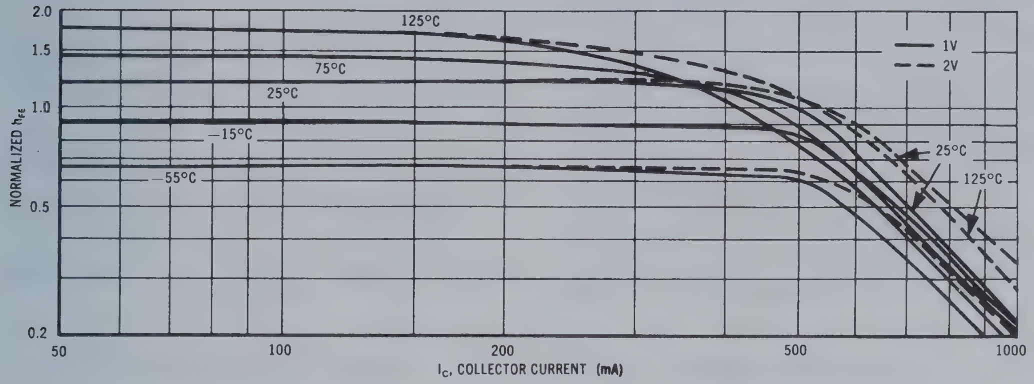
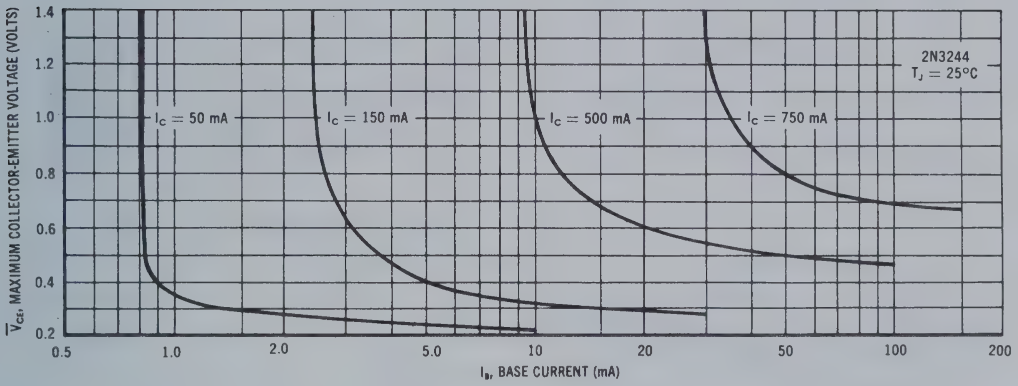


FIGURE 2 — COLLECTOR-EMITTER SATURATION VOLTAGE CHARACTERISTICS



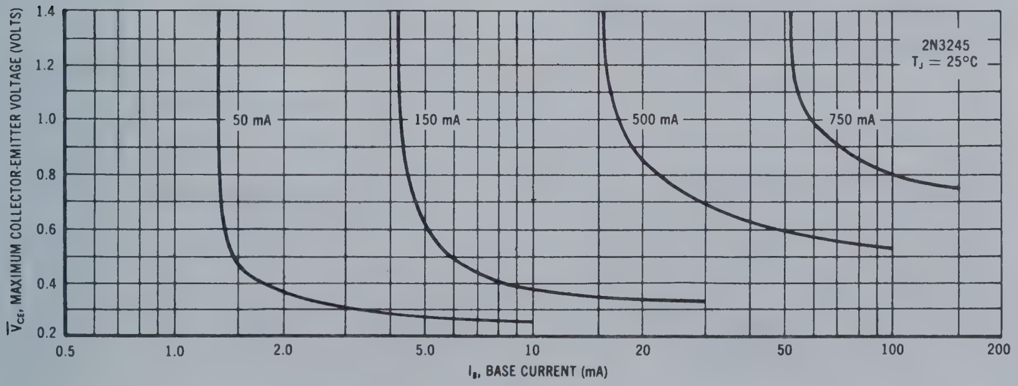


FIGURE 3 — MAXIMUM SATURATION VOLTAGES

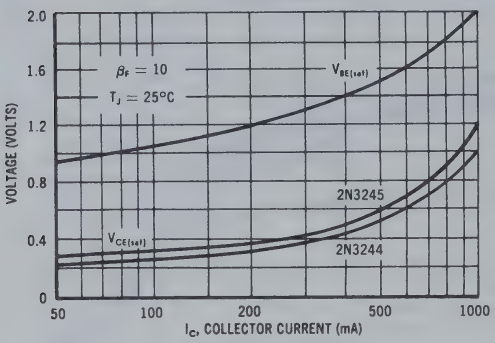


FIGURE 4 — TYPICAL TEMPERATURE COEFFICIENTS

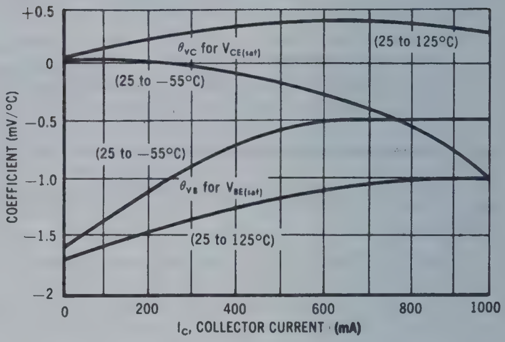


FIGURE 5 — JUNCTION CAPACITANCE

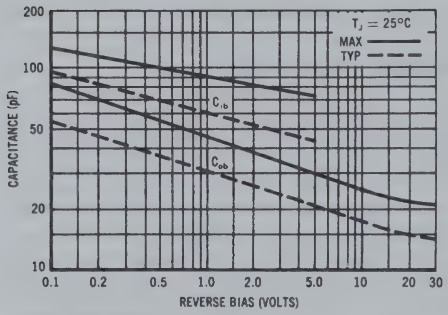


FIGURE 6 — TYPICAL SWITCHING TIMES

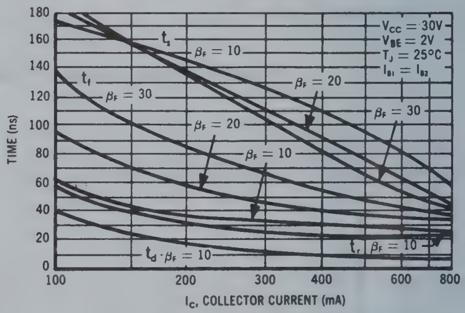


FIGURE 7 — CHARGE DATA

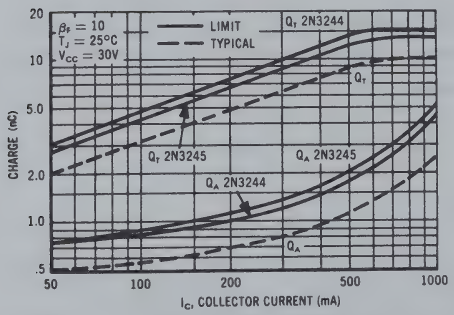
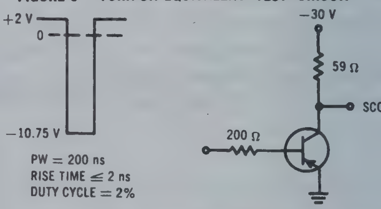
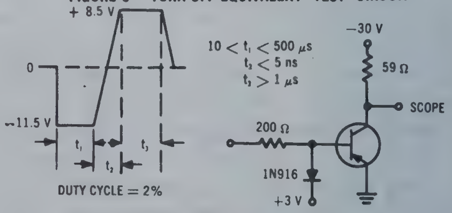


FIGURE 8 — TURN-ON EQUIVALENT TEST CIRCUIT



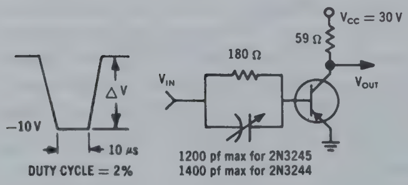
+2 V
0
−10.75 V
PW = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE = 2%
−30 V
59 Ω
SCOPE
200 Ω

FIGURE 9 — TURN-OFF EQUIVALENT TEST CIRCUIT



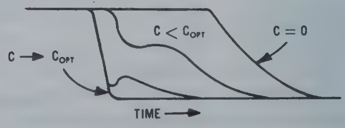
+ 8.5 V
0
−11.5 V
t_1
t_2
t_3
$10 < t_1 < 500\ \mu s$
$t_2 < 5$ ns
$t_3 > 1\ \mu s$
DUTY CYCLE = 2%
−30 V
59 Ω
SCOPE
200 Ω
1N916
+3 V

FIGURE 10 — Q_T TEST CIRCUIT



−10 V
ΔV
10 μs
DUTY CYCLE = 2%
V_{IN}
180 Ω
59 Ω
$V_{CC} = 30$ V
V_{OUT}
1200 pf max for 2N3245
1400 pf max for 2N3244

FIGURE 11 — TURN-OFF WAVEFORM



$C < C_{OPT}$
C = 0
$C \rightarrow C_{OPT}$
TIME →

2N3248 (SILICON)
2N3249

CASE 22
(TO-18)

Collector connected to case

PNP silicon annular transistors for low-level, high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ 25°C Ambient Temperature Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — t_{on} CIRCUIT

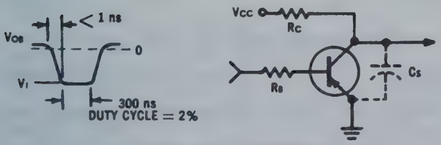
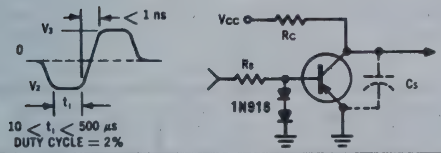

< 1 ns
V_{OB}
0
V_1
300 ns
DUTY CYCLE = 2%
Vcc
Rc
RB
Cs

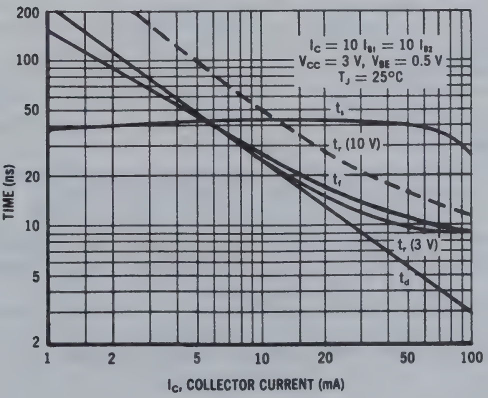
FIGURE 2 — t_{off} CIRCUIT


< 1 ns
V_3
0
V_2
t_1
$10 < t_1 < 500$ µs
DUTY CYCLE = 2%
Vcc
Rc
RB
1N916
Cs

I_C mA	V_{CC} volts	R_B ohms	R_C ohms	$C_{S(max)}$* pF	V_{OB} volts	V_1 volts	V_2 volts	V_3 volts
10	3	10 K	285	4	+0.5	−10.6	−10.9	+9.1
100	10	1 K	95	12	+0.5	−10.7	−11.3	+8.7

*Total shunt capacitance of test jig and connectors.

FIGURE 3 — TYPICAL SWITCHING TIMES



2N3248, 2N3249 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless othewise noted)

Characteristic	Fig.No.	Symbol	Min	Max	Unit
Collector-Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc) (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc, T_A = 100°C)		I_{CEX}	— —	0.05 5.0	μAdc
Base Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc)		I_{BL}	—	50	nAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	15	—	Vdc
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Saturation Voltage [1] (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc) 2N3248 2N3249	7,8	$V_{CE(sat)}$	— — — —	0.125 0.25 0.4 0.45	Vdc
Base-Emitter Saturation Voltage [1] (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	8	$V_{BE(sat)}$	0.6 — 0.7	0.9 1.1 1.3	Vdc
DC Current Gain [1] (I_C = 0.1 mAdc, V_{CE} = 1 Vdc) 2N3248 2N3249 (I_C = 1.0 mAdc, V_{CE} = 1 Vdc) 2N3248 2N3249 (I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N3248 2N3249 (I_C = 50 mAdc, V_{CE} = 1 Vdc) 2N3248 2N3249 (I_C = 100 mAdc, V_{CE} = 1 Vdc) 2N3248 2N3249	4	h_{FE}	50 100 50 100 50 100 35 75 25 35	— — — — 150 300 — — — —	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	6	C_{ob}	—	8.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	6	C_{ib}	—	8.0	pF
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N3248 2N3249		f_T	250 300	— —	MHz
Total Control Charge (I_C = 10 mA, I_B = 0.25 mA, V_{CC} = 3 V)	5,10	Q_T	—	150	pC
Delay Time — I_C = 100 mA, I_B = 10 mA, $V_{BE(off)}$ = 0.5 V, V_{CC} = 10 V	1,3	t_d	—	5.0	ns
Rise Time		t_r	—	15	ns
Storage Time — I_C = 100 mA, I_{B1} = I_{B2} = 10 mA, V_{CC} = 10 V	2,3	t_s	—	60	ns
Fall Time		t_f	—	20	ns
Turn-On Time — I_C = 10 mA, I_{B1} = 1 mA, $V_{BE(off)}$ = 0.5 V, V_{CC} = 3 V	1,3	t_{on}	—	90	ns
Turn-Off Time — I_C = 10 mA, I_{B1} = I_{B2} = 1 mA, V_{CC} = 3 V	2,3	t_{off}	—	100	ns

(1) Pulse Test: PW = 300 μs, Duty Cycle ≦ 2%

FIGURE 4 — MINIMUM CURRENT GAIN CHARACTERISTICS

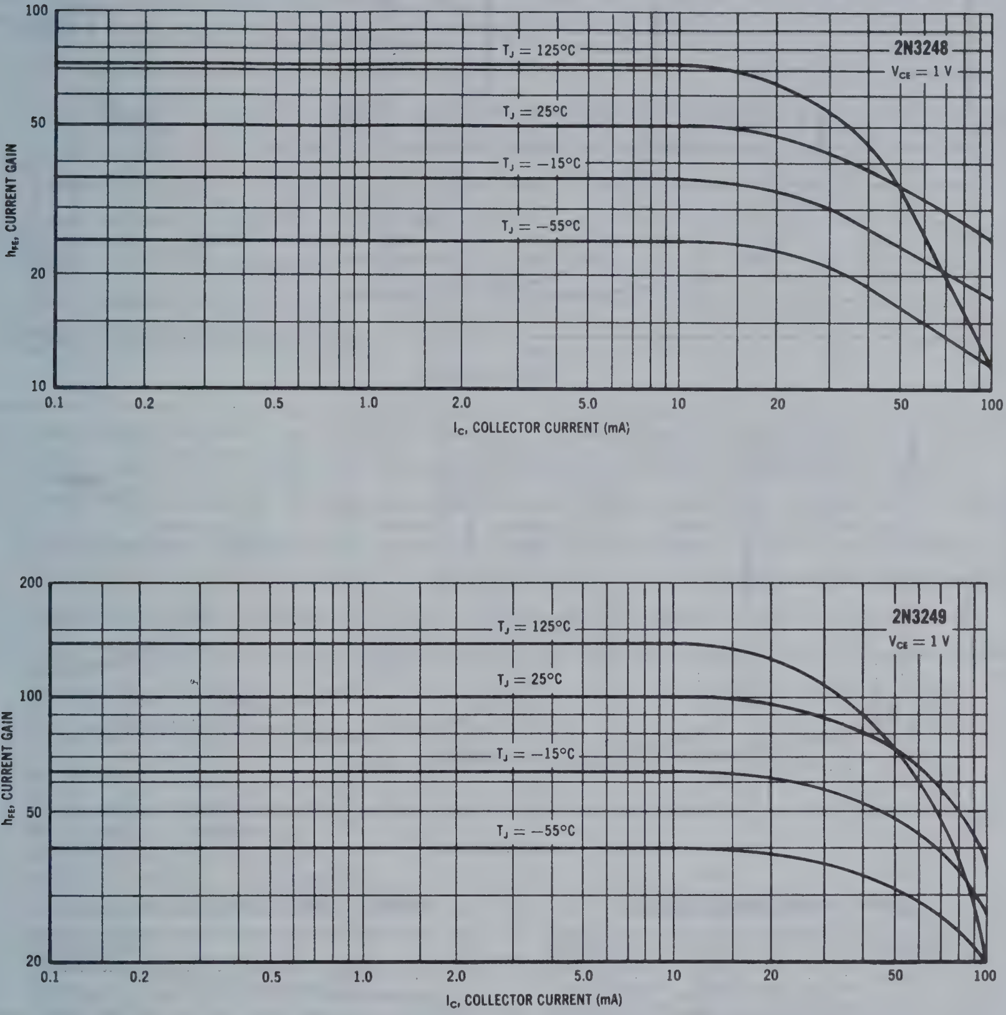


FIGURE 5 — MAXIMUM CHARGE DATA

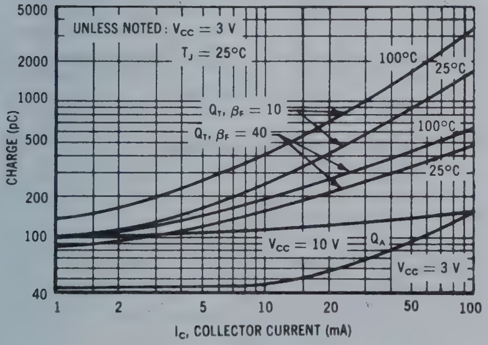


FIGURE 6 — JUNCTION CAPACITANCE

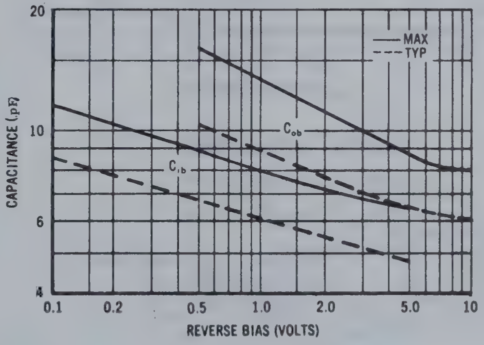


FIGURE 7 COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

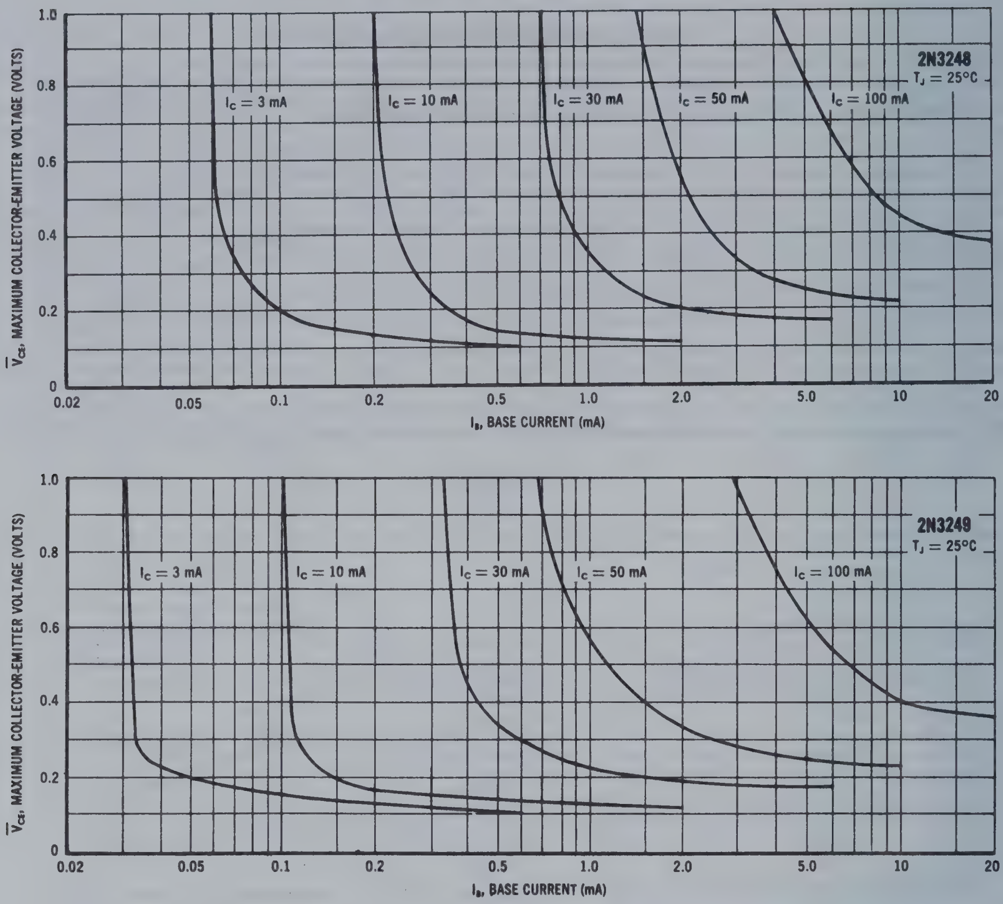


FIGURE 8 — SATURATION VOLTAGE LIMITS

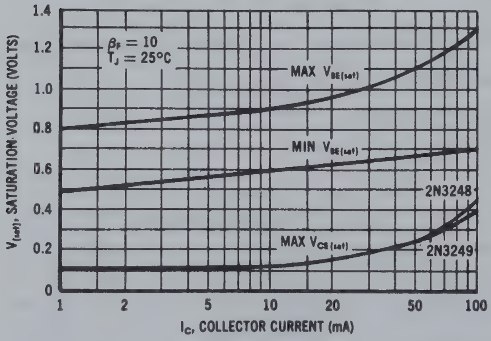
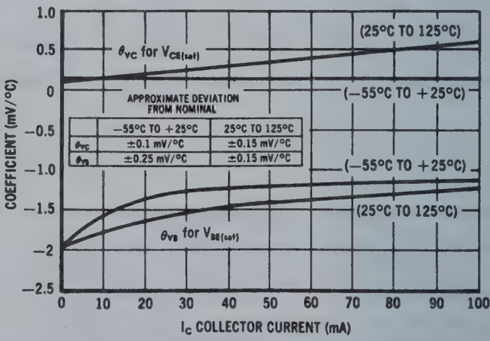


FIGURE 9 — TYPICAL TEMPERATURE COEFFICIENTS



APPROXIMATE DEVIATION FROM NOMINAL

	−55°C TO +25°C	25°C TO 125°C
θ_{VC}	±0.1 mV/°C	±0.15 mV/°C
θ_{VB}	±0.25 mV/°C	±0.15 mV/°C

FIGURE 10 — Q_T TEST CIRCUIT

VALUES REFER TO $I_C = 10$ mA TEST POINT

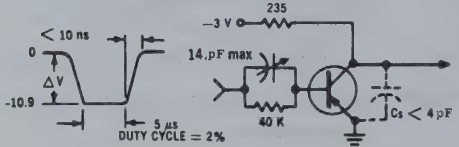
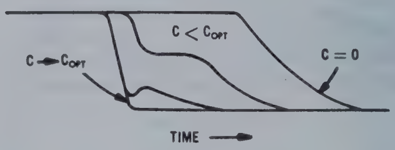

< 10 ns
0
ΔV
-10.9
5 μs
DUTY CYCLE = 2%
235
−3 V
14 pF max
40 K
$C_S < 4$ pF

FIGURE 11 — TURN-OFF WAVE FORM


$C < C_{OPT}$
$C \to C_{OPT}$
C = 0
TIME

2N3250, A (SILICON)
2N3251, A

2N3250A JAN, JTX AVAILABLE
2N3251A JAN, JTX AVAILABLE

PNP silicon annular transistors for high-speed switching and amplifier applications.

CASE 22
(TO-18)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3250 2N3251	2N3250A 2N3251A	Unit
Collector-Base Voltage	V_{CB}	50	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	1.2 6.9		Watts mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.36 2.06		Watts mW/°C
Junction Operating Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	−65 to +200		°C
Thermal Resistance, Junction to Ambient Thermal Resistance, Junction to Case	θ_{JA} θ_{JC}	0.49 0.15		°C/mW °C/mW

2N3250, A, 2N3251, A (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{CEX}	--	20	nAdc
Base Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{BL}	--	50	nAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc)	2N3250, 2N3251 2N3250A, 2N3251A	BV_{CBO}	50 60	--	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc)	2N3250, 2N3251 2N3250A, 2N3251A	BV_{CEO}	40 60	--	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc)		BV_{EBO}	5.0	--	Vdc
Collector Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{CE(sat)}$	--	0.25	Vdc
(I_C = 50 mAdc, I_B = 5 mAdc)			--	0.5	
Base-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	0.6	0.9	Vdc
(I_C = 50 mAdc, I_B = 5 mAdc)			--	1.2	
DC Forward Current Transfer Ratio (1) (I_C = 0.1 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A	h_{FE}	40 80	-- --	--
(I_C = 1 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		45 90	-- --	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		50 100	150 300	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		15 30	-- --	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	--	6.0	pF
Input Capacitance (V_{CB} = 1 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	--	8.0	pF
Current-Gain - Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3250, 2N3250A 2N3251, 2N3251A	f_T	250 300	-- --	MHz

SMALL SIGNAL CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{fe}	50 100	200 400	--
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{re}	-- --	10 20	$X10^{-4}$
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{ie}	1.0 2.0	6.0 12	kohms
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{oe}	4.0 10	40 60	μ mhos
Collector-Base Time Constant (I_C = 10 mA, V_{CE} = 20 V)		$r'_b C_C$	--	250	ps
Noise Figure (I_C = 100 μA, V_{CE} = 5 V, R_S = 1 kΩ, f = 100 Hz)		NF	--	6.0	dB

(1) Pulse Test: PW = 300 μs, Duty Cycle = 2%

SWITCHING CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic			Symbol	Max	Unit
Delay Time	(V_{CC} = 3 Vdc, V_{BE} = 0.5 Vdc I_C = 10 mAdc, I_{B1} = 1 mA)		t_d	35	ns
Rise Time			t_r	35	ns
Storage Time	(I_{B1} = I_{B2} = 1 mAdc V_{CC} = 3V)	2N3250, 2N3250A 2N3251, 2N3251A	t_s	175 200	ns
Fall Time			t_f	50	ns

SWITCHING TIME CHARACTERISTICS

FIGURE 1 — DELAY AND RISE TIME

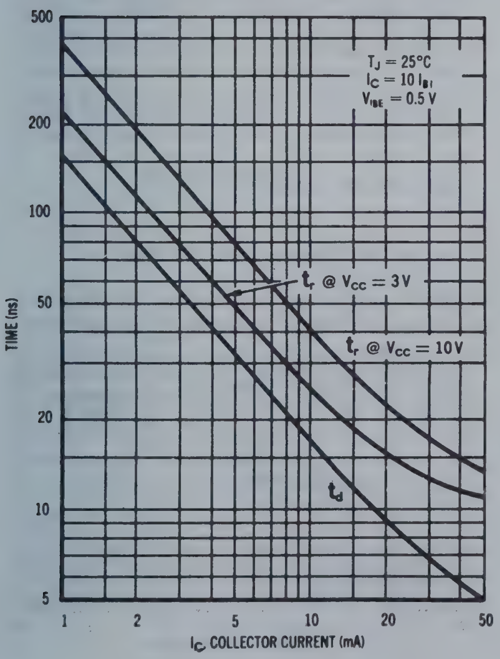
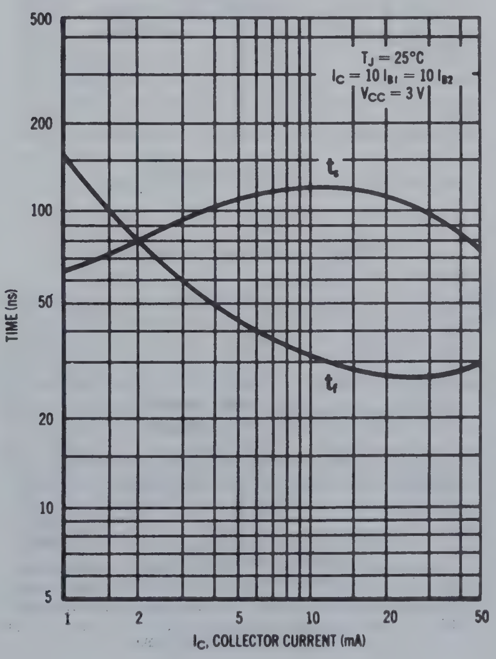


FIGURE 2 — STORAGE AND FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS
NOISE FIGURE VARIATIONS

($V_{CE} = 6\,V$, $T_A = 25°C$)

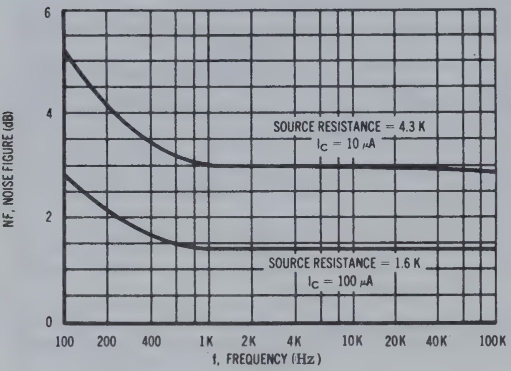


FIGURE 3 — FREQUENCY

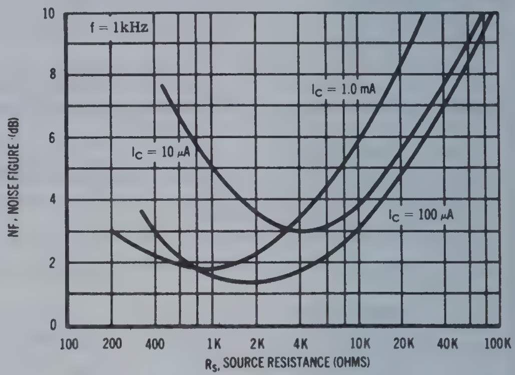


FIGURE 4 — SOURCE RESISTANCE

h PARAMETERS

$V_{CE} = 10\,V$, $f = 1\,kHz$, $T_A = 25°C$

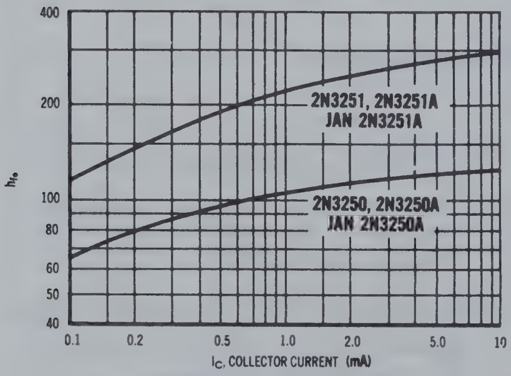


FIGURE 5 — CURRENT GAIN

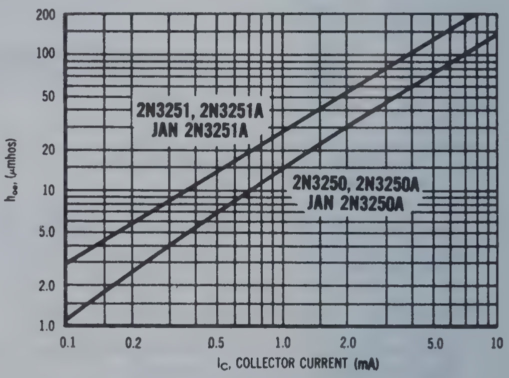


FIGURE 6 — OUTPUT ADMITTANCE

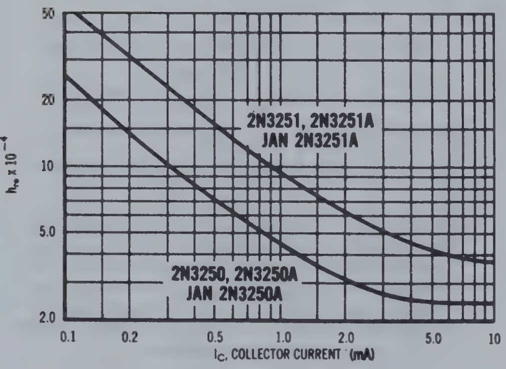


FIGURE 7 — VOLTAGE FEEDBACK RATIO

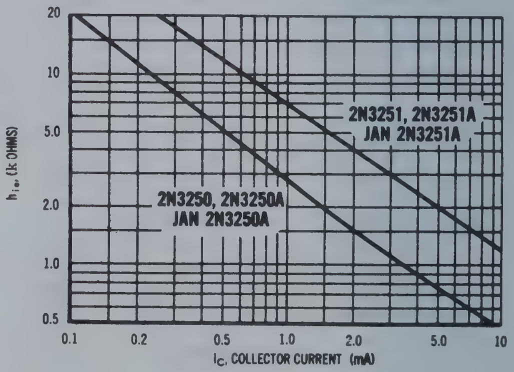


FIGURE 8 — INPUT IMPEDANCE

FIGURE 9 — NORMALIZED CURRENT GAIN CHARACTERISTICS

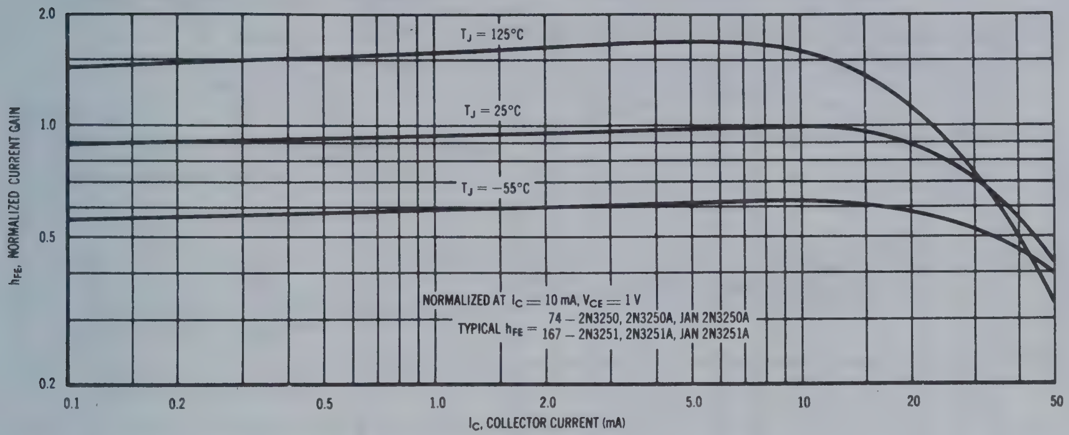
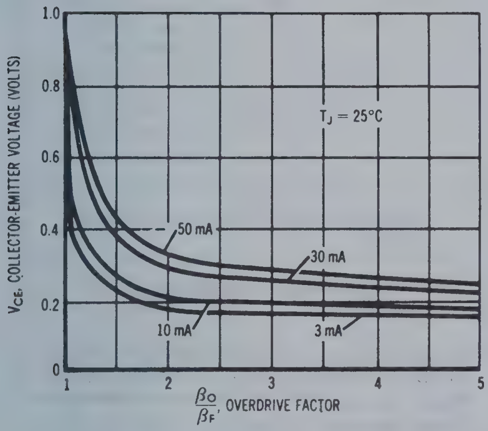


FIGURE 10 — COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_O is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3251, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 10 mA.

Observe that at $I_C = 10$ mA an overdrive factor of at least 2.5 is required to drive the transistor well into the saturation region. From Figure 9, it is seen that h_{FE} @ 1 volt is typically 167 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design) . . .

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} \text{ @ 1 Volt}}{I_C/I_{BF}} \qquad 2.5 = \frac{167}{10\text{ mA}/I_{BF}} \qquad I_{BF} \approx 6.68\text{ mA typ}$$

FIGURE 11 — SATURATION VOLTAGES

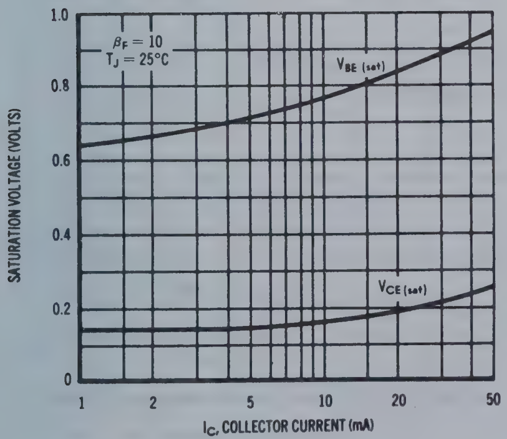


FIGURE 12 — TEMPERATURE COEFFICIENTS

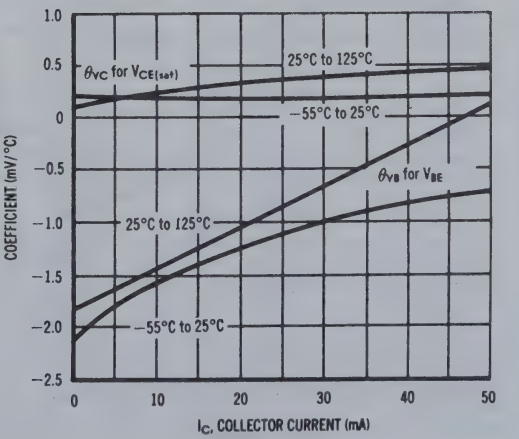


FIGURE 13 — f_T AND $r_b'C_C$ versus I_C

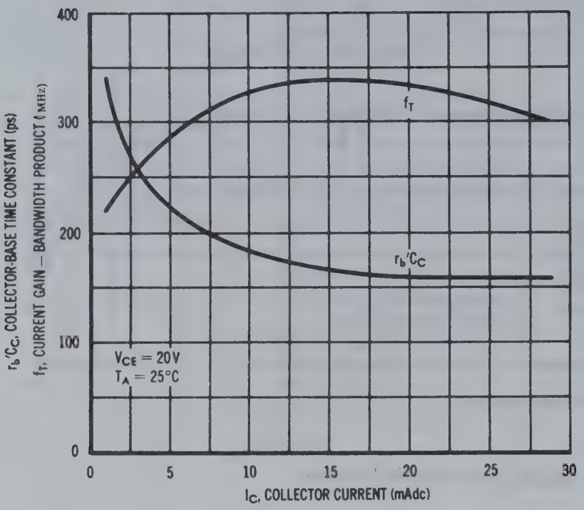


FIGURE 14 — 30 MC EQUIVALENT CIRCUIT

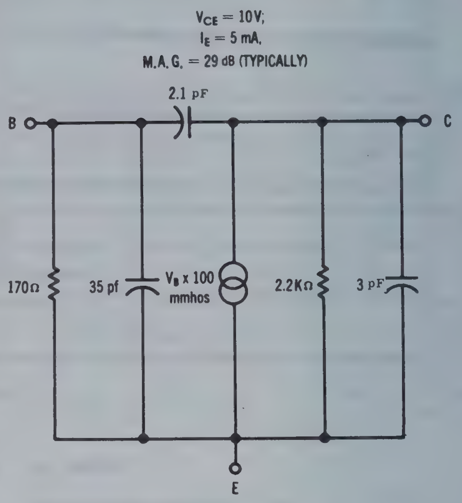

V_{CE} = 10V;
I_E = 5 mA,
M.A.G. = 29 dB (TYPICALLY)
2.1 pF
B
C
170Ω
35 pf
V_B x 100
mmhos
2.2KΩ
3 pF
E

FIGURE 15 — JUNCTION CAPACITANCE

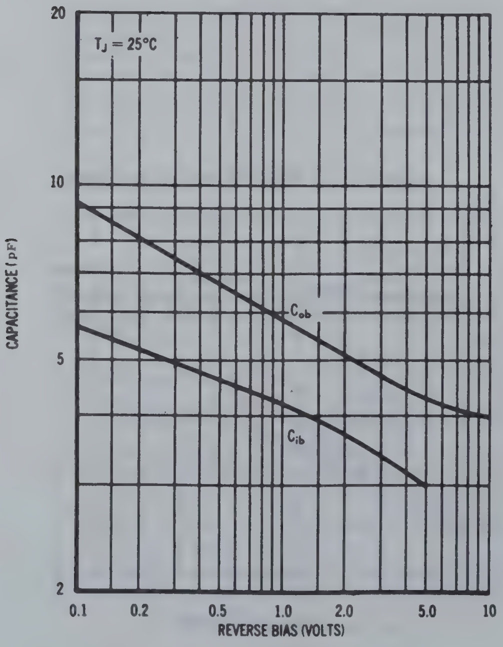
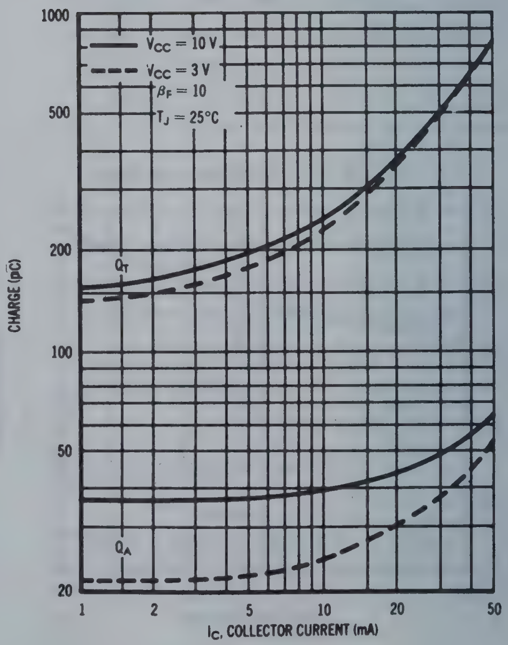


FIGURE 16 — CHARGE DATA



2N3252, 2N3253 (SILICON)

2N3253 JAN AVAILABLE

2N3444

2N3444 JAN AVAILABLE

NPN silicon annular transistors for high-current saturated switching and core driver applications.

CASE 31
(TO-5)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3252	2N3253	2N3444	Unit
Collector-Base Voltage	V_{CB}	60	75	80	Vdc
Collector-Emitter Voltage	V_{CEO}	30	40	50	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	← 5.0 → ← 28.6 →			Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	← 1.0 → ← 5.71 →			Watt mW/°C
Junction Operating Temperature Range	T_J	← -65 to +200 →			°C
Storage Temperature Range	T_{stg}	← -65 to +200 →			°C
Thermal Resistance:	θ_{JC} θ_{JA}	35 0.175			°C/W °C/mW

SWITCHING CHARACTERISTICS (T_A = 25°C unless otherwise noted)

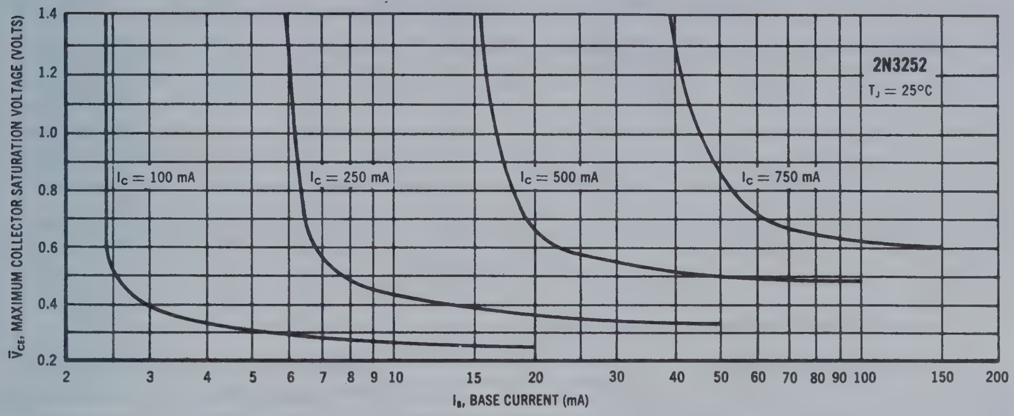
Characteristic		Symbol	Min	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	12	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
Current Gain-Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3252 2N3253, 2N3444	f_T	200 175	— —	MHz
Total Control Charge (I_C = 500 mAdc, I_{B1} = 50 mAdc, V_{CC} = 30 V)		Q_T	—	5.0	nC
Delay Time	I_C = 500 mAdc, I_{B1} = 50 mAdc	t_d	—	15	ns
Rise Time	V_{CC} = 30 V, V_{BE} = 2 V 2N3252 2N3253, 2N3444	t_r	— —	30 35	ns
Storage Time	I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc	t_s	—	40	ns
Fall Time	V_{CC} = 30 V	t_f	—	30	ns

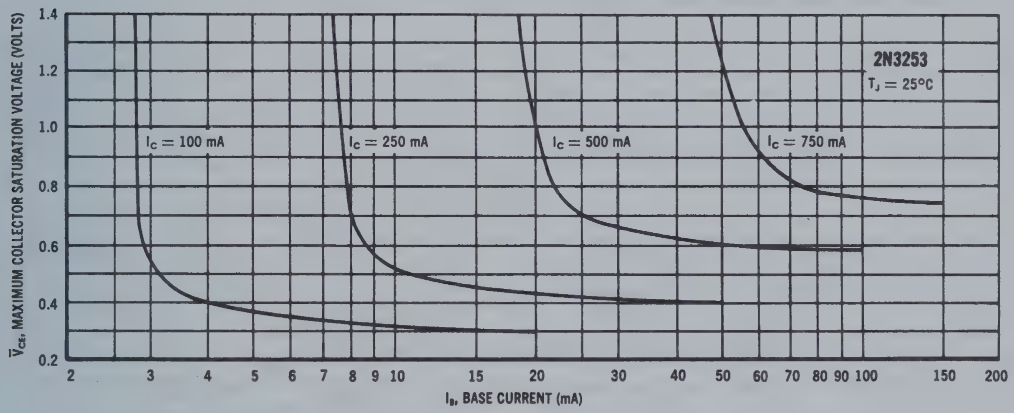
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

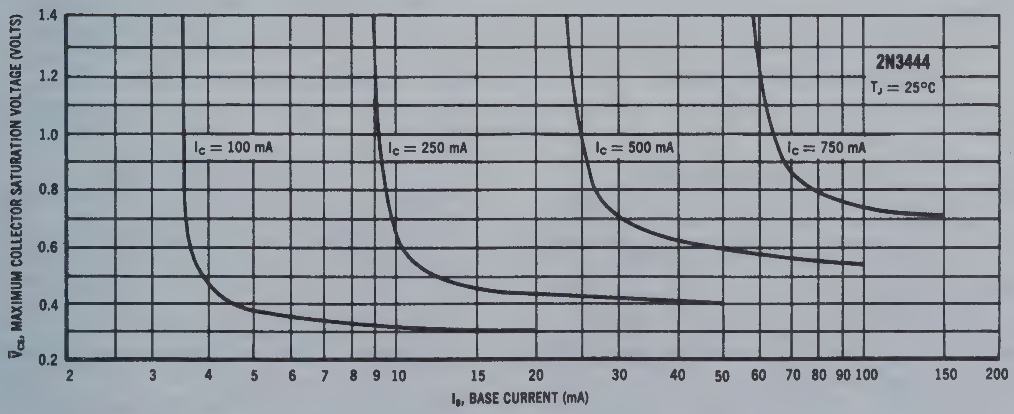
Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N3252		—	0.50	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 100°C)	2N3252			75.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N3253, 2N3444			0.50	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 100°C)	2N3253, 2N3444			75.0	
Emitter Cutoff Current		I_{EBO}			μAdc
(V_{BF} = 4 Vdc, I_C = 0)			—	0.05	
Collector Cutoff Current		I_{CEX}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3252		—	0.5	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3253, 2N3444,		—	0.5	
Base Cutoff Current		I_{BL}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3252		—	0.50	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3253, 2N3444		—	0.50	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3252		60	—	
	2N3253		75	—	
	2N3444		80	—	
Collector-Emitter Breakdown Voltage (1)		BV_{CEO}			Vdc
(I_C = 10 mAdc, pulsed, I_B = 0)	2N3252		30	—	
	2N3253		40	—	
	2N3444		50	—	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)			5.0	—	
Collector Saturation Voltage (1)		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N3252		—	0.3	
	2N3253, 2N3444		—	0.35	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3252		—	0.5	
	2N3253, 2N3444		—	0.60	
(I_C = 1.0 Adc, I_B = 100 mAdc)	2N3252		—	1.0	
	2N3253, 2N3444		—	1.2	
Base-Emitter Saturation Voltage (1)		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)			0.7	1.3	
(I_C = 1.0 Adc, I_B = 100 mAdc)			—	1.8	
DC Forward Current Transfer Ratio (1)		h_{FE}			—
(I_C = 150 mAdc, V_{CE} = 1 Vdc)	2N3252		30	—	
	2N3253		25	—	
	2N3444		20	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)	2N3252		30	90	
	2N3253		25	75	
	2N3444		20	60	
(I_C = 1 Adc, V_{CE} = 5 Vdc)	2N3252		25	—	
	2N3253		20	—	
	2N3444		15	—	

(1) Pulse Test: Pulse width = 300 μs, duty cycle = 2%

COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

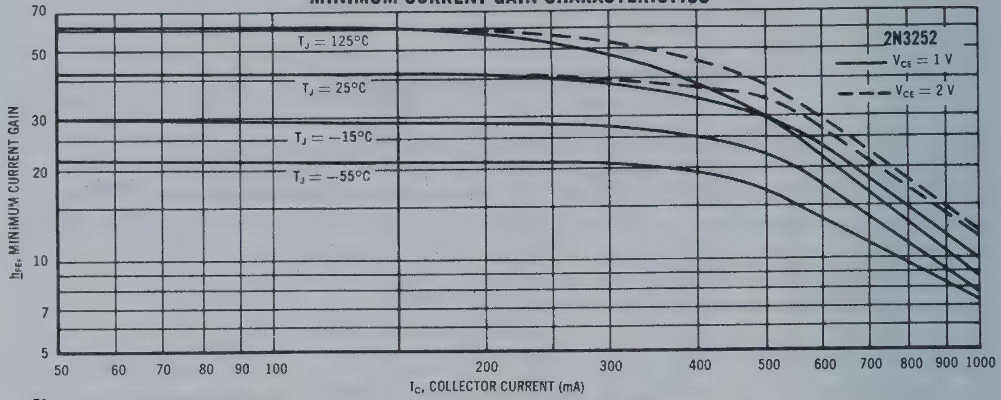


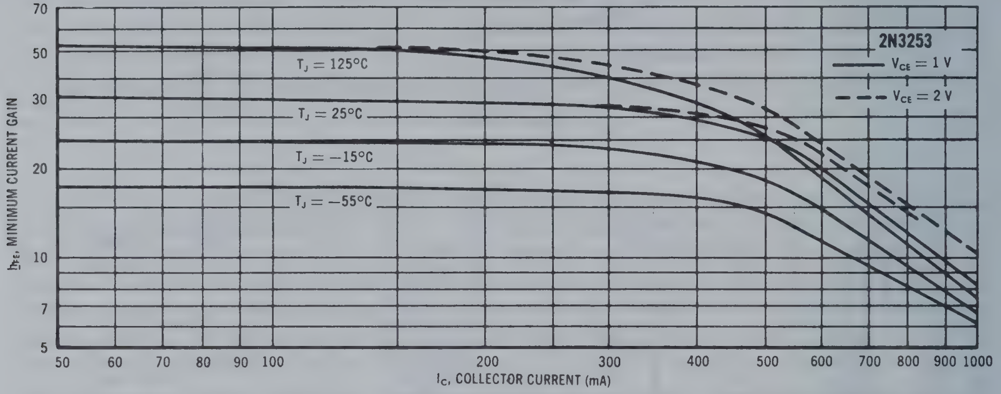


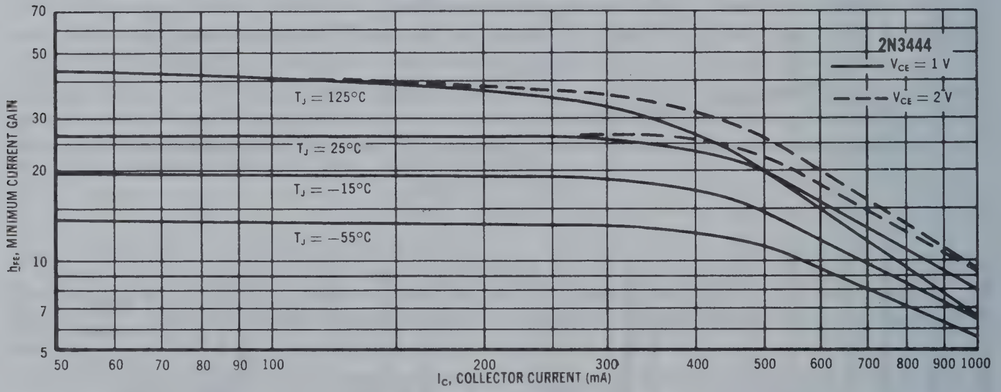


2N3252, 2N3253, 2N3444 (continued)

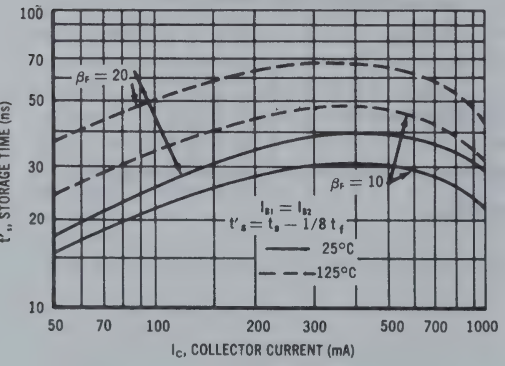
MINIMUM CURRENT GAIN CHARACTERISTICS



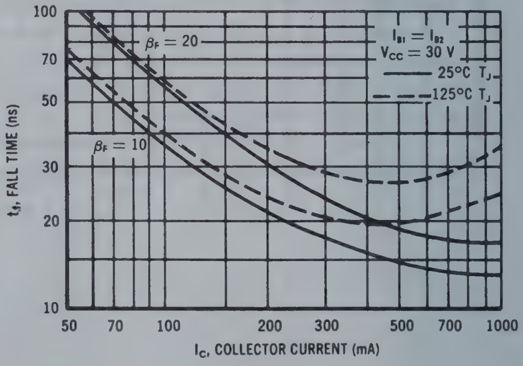




TYPICAL STORAGE TIME VARIATIONS

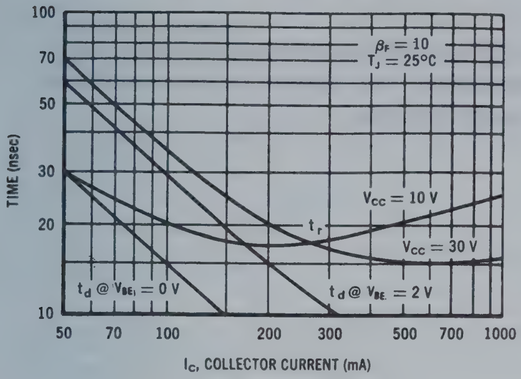


TYPICAL FALL TIME VARIATIONS

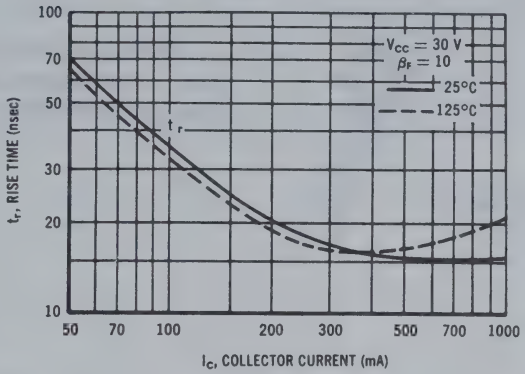


2N3252, 2N3253, 2N3444 (continued)

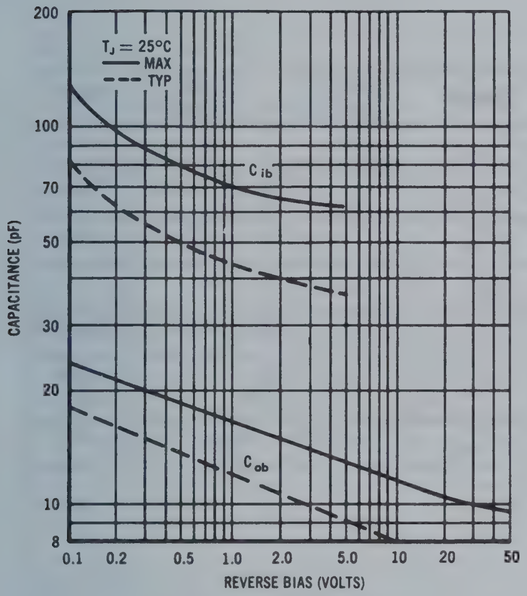
TYPICAL TURN-ON TIME VARIATIONS WITH VOLTAGE



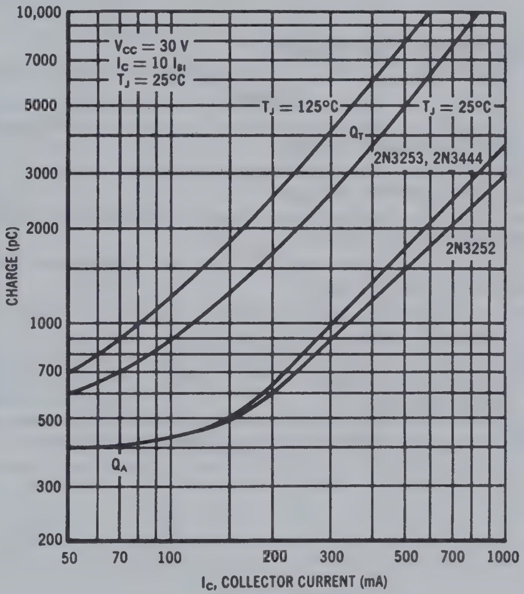
TYPICAL RISE TIME VARIATIONS WITH TEMPERATURE



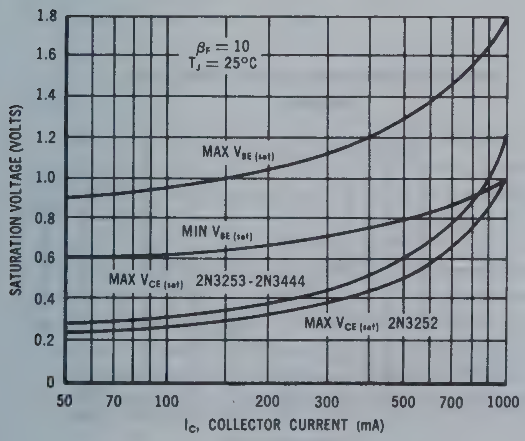
JUNCTION CAPACITANCE VARIATIONS



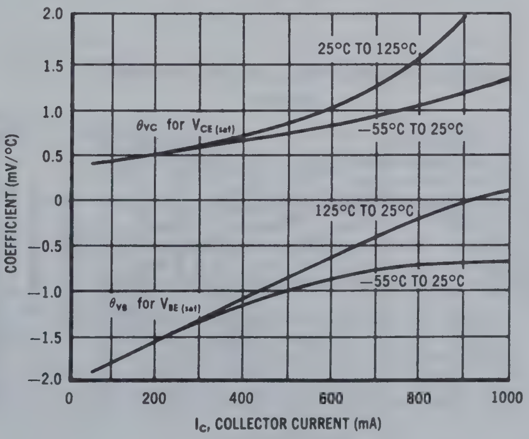
MAXIMUM CHARGE DATA



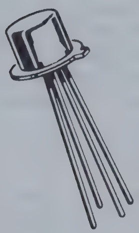
LIMITS OF SATURATION VOLTAGES



TYPICAL TEMPERATURE COEFFICIENTS



2N3279 thru 2N3282 (GERMANIUM)



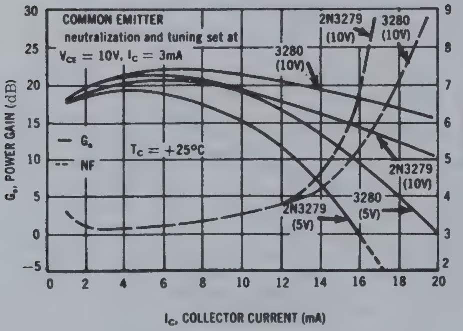
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

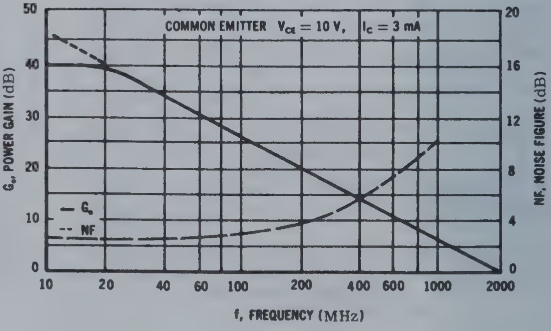
MAXIMUM RATINGS

Rating	Symbol	2N3279 2N3280	2N3281 2N3282	Unit
Collector-Emitter Voltage	V_{CEO}	20	15	Vdc
Collector-Emitter Voltage	V_{CES}	30		Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	1.0	0.5	
Collector Current	I_C	50		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	100 1.33		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT
200 MHz



NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



2N3279 thru 2N3282 (Continued)

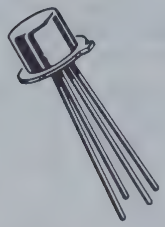
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage		BV_{CEO}				Vdc
(I_C = 2.0 mAdc, I_B = 0)	2N3279, 2N3280		20	-	-	
	2N3281, 2N3282		15	-	-	
Collector-Emitter Breakdown Voltage		BV_{CES}				Vdc
(I_C = 100 μAdc, V_{BE} = 0)			30	-	-	
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 100 μAdc, I_E = 0)			30	-	-	
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 10 Vdc, I_E = 0)	All Types		-	1.0	5.0	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +55°C)	2N3279, 2N3280		-	-	50	
Emitter Cutoff Current		I_{EBO}				μAdc
(V_{BE} = 0.5 Vdc, I_C = 0)	2N3281, 2N3282		-	-	100	
(V_{BE} = 0.75 Vdc, I_C = 0)	2N3279, 2N3280		-	-	100	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	2N3279, 2N3280		10	-	70	
	2N3281, 2N3282		10	-	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 5.0 mAdc, I_B = 1.0 mAdc)	2N3279, 2N3280		-	-	0.3	
	2N3281, 2N3282		-	-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 5.0 mAdc, I_B = 1.0 mAdc)	2N3279, 2N3280		-	-	1.0	
	2N3281, 2N3282		-	-	1.5	
DYNAMIC CHARACTERISTICS						
Current-Gain–Bandwidth Product		f_T				MHz
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	2N3279, 2N3280		400	500	800	
	2N3281, 2N3282		300	400	800	
Maximum Frequency of Oscillation		f_{max}				MHz
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc)			-	2000	-	
Output Capacitance*		C_{ob}*				pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3279		-	0.9	1.0	
	2N3280 thru 2N3282		-	1.0	1.2	
Small-Signal Current Gain		h_{fe}				-
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3279, 2N3280		10	-	100	
	2N3281, 2N3282		10	-	150	
Collector-Base Time Constant		$r_b'C_c$				ps
(I_E = 3.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	2N3279, 2N3280		3.0	5.0	10	
	2N3281, 2N3282		3.0	5.0	15	
Noise Figure		NF				dB
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz)	2N3279, 2N3280		-	2.9	3.5	
	2N3281, 2N3282		-	4.0	5.0	
FUNCTIONAL TESTS						
Power Gain		G_{pe}				dB
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz)	2N3279, 2N3280		17	-	23	
	2N3281, 2N3282		16	-	23	
Power Gain (AGC)**		G_{pe}(AGC)**				dB
(I_C = 20 mAdc, V_{CE} = 5.0 Vdc, f = 200 MHz)	2N3279, 2N3281		-	-	0	
	2N3280, 2N3282		-	0	-	

*C_{ob} is measured in a guarded circuit such that the can capacitance is not included.

**AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3.0 mAdc operation.

2N3283 thru 2N3286 (GERMANIUM)



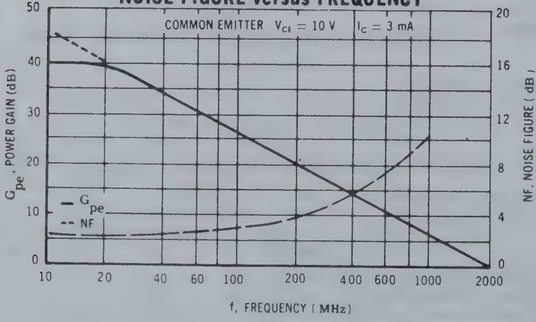
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for TV and FM, RF and IF amplifier, oscillator and general purpose high-gain, low-noise amplifier applications.

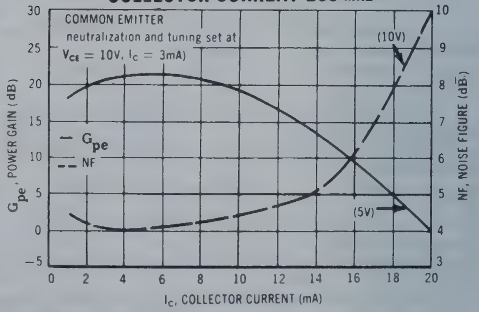
MAXIMUM RATINGS

Rating	Symbol	2N3283 2N3284	2N3285 2N3286	Unit
Collector-Emitter Voltage	V_{CES}	25	20	Vdc
Collector-Base Voltage	V_{CB}	25	20	Vdc
Emitter-Base Voltage	V_{EB}	0.5		Vdc
Collector Current	I_C	50		mAdc
Total Device Dissipation @ T_A = 25°C	P_D	100		mW
Derate above 25°C		1.33		mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT 200 MHZ



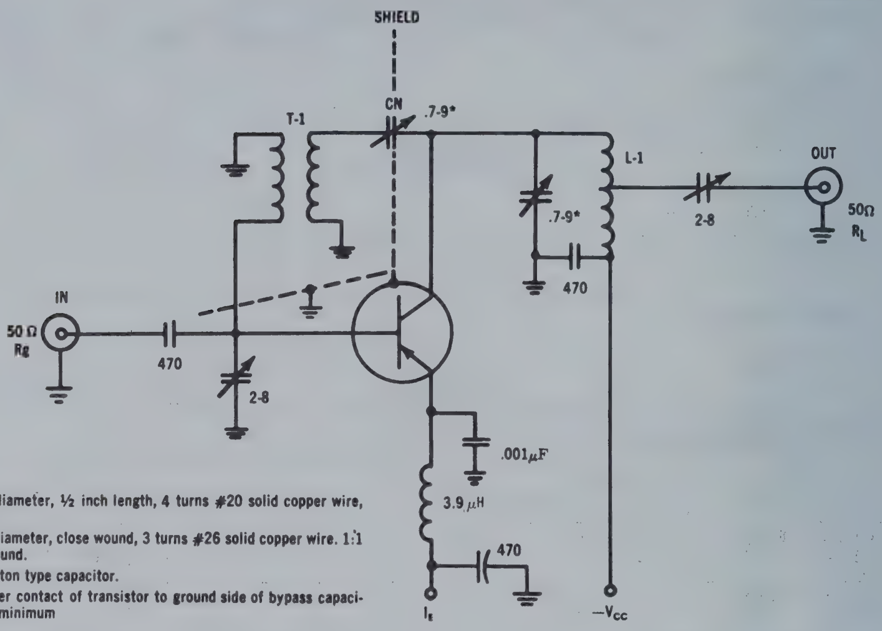
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0) 2N3283, 2N3284	BV_{CES}	25	30	-	Vdc
2N3285, 2N3286		20	25	-	
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	2.0	10	μAdc
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)	I_{EBO}	-	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc) 2N3283, 2N3284	h_{FE}	10	30	-	-
2N3285, 2N3286		5.0	15	-	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	400	800	MHz
Maximum Frequency of Oscillation (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	f_{max}	-	2000	-	MHz
Output Capacitance* (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}*	-	1.0	1.5	pF
Small-Signal Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3283, 2N3284	h_{fe}	10	-	200	-
2N3285, 2N3286		5.0	-	200	
Collector-Base Time Constant (I_E = 3.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	10	25	ps
Noise Figure (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz) 2N3283	NF	-	4.0	5.0	dB
2N3284		-	5.0	6.0	
2N3286		-	5.0	-	
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain (V_{CE} = 10 Vdc, I_C = 3.0 mAdc, f = 200 MHz) 2N3283, 2N3284	G_{pe}	16	20	23	dB
2N3286		14	-	-	
Power Gain (AGC)** (V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200 MHz, Figure 1) 2N3283	G_{pe}(AGC)**	-	-	0	dB
2N3284		-	0	-	
Power Output (V_{EE} = 12 Vdc, f = 247 MHz) 2N3285	P_{out}	2.0	-	-	mW

* C_{ob} is measured in a guarded circuit such that the can capacitance is not included.

** AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3.0 mAdc operation.

FIGURE 1 — 200 MHz POWER GAIN AND NOISE FIGURE TEST CIRCUIT


SHIELD
T-1
CN
.7-9*
L-1
OUT
.7-9*
2-8
50Ω
R_L
470
IN
50 Ω
Rg
470
2-8
.001μF
3.9 μH
470
I_E
$-V_{CC}$

NOTES:

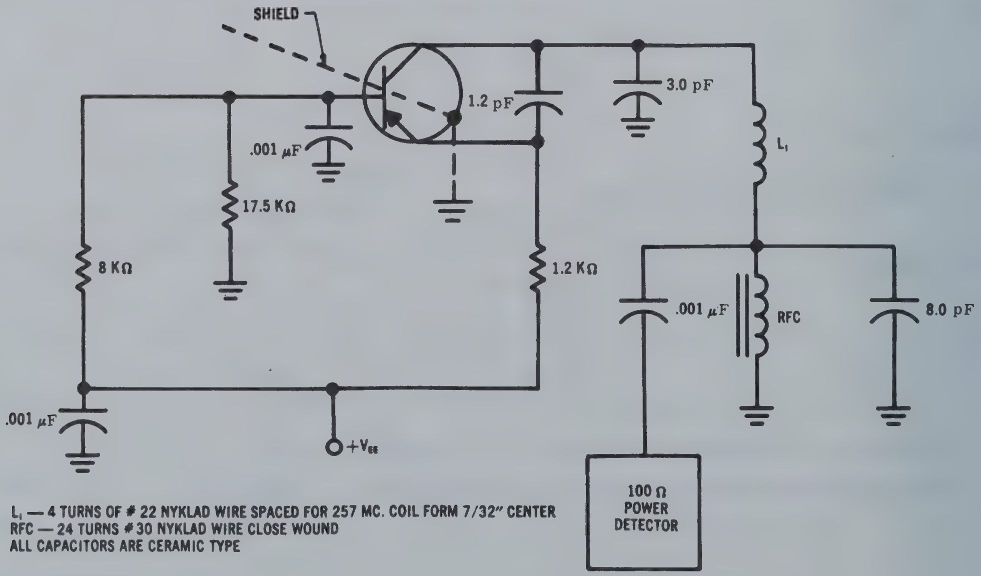
L-1 ¼ inch inside diameter, ½ inch length, 4 turns #20 solid copper wire, center tapped.

T-1 ¼ inch inside diameter, close wound, 3 turns #26 solid copper wire. 1:1 ratio bi-filler wound.

* High Quality piston type capacitor.

Distance from emitter contact of transistor to ground side of bypass capacitor should be kept minimum

FIGURE 2 — 257 MHz OSCILLATOR POWER OUTPUT TEST CIRCUIT


SHIELD
1.2 pF
3.0 pF
.001 μF
L_1
17.5 KΩ
8 KΩ
1.2 KΩ
.001 μF
RFC
8.0 pF
.001 μF
$+V_{EE}$
100 Ω
POWER
DETECTOR

L_1 — 4 TURNS OF # 22 NYKLAD WIRE SPACED FOR 257 MC. COIL FORM 7/32" CENTER
RFC — 24 TURNS # 30 NYKLAD WIRE CLOSE WOUND
ALL CAPACITORS ARE CERAMIC TYPE

2N3287 thru 2N3290 (SILICON)

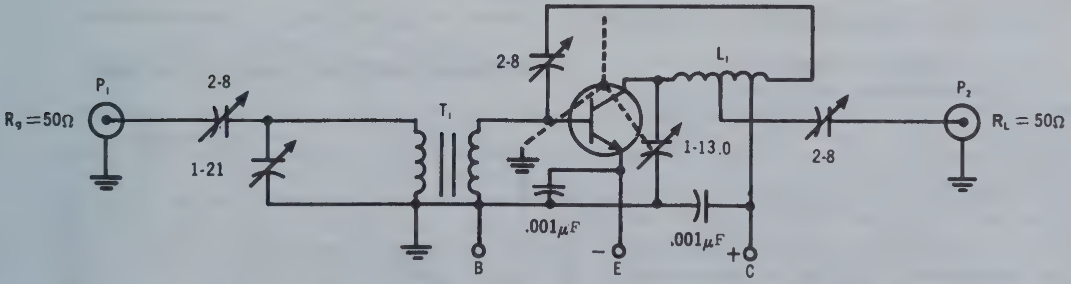
CASE 20
(TO-72)

NPN silicon annular transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3287 2N3288	2N3289 2N3290	Unit
Collector - Base Voltage	V_{CB}	40	30	Volts
Collector - Emitter Voltage	V_{CES}	40	30	Volts
Collector - Emitter Voltage	V_{CEO}	20	15	Volts
Emitter - Base Voltage	V_{EB}	3.0	3.0	Volts
Collector Current	I_C	50	50	mA
Power Dissipation at 25°C Case Above 25°C derate 1.71 mW/°C	P_D	300	300	mW
Power Dissipation at 25° C amb. Above 25°C derate 1.14 mW/°C	P_D	200	200	mW
Junction Temperature	T_J,	+200	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	-65 to +200	°C

200 MHz TEST CIRCUIT: POWER GAIN, NOISE FIGURE, & AGC



L_1-6 turns of #16 tinned wire; ⅜″ ID; Air wound; winding length ¾″; V_{CC} feeds tap 4¾ turns from collector end; output tap 3½ turns from collector end.

T_1-3 turns primary and secondary Bifilar wound (close wound) on ¼″ ceramic form (cambion type) with brass slug. #22 enameled wire.

P_1-General Radio 874 G6 Pad (6dB)
P_2-General Radio 874 G6 Pad (6dB)

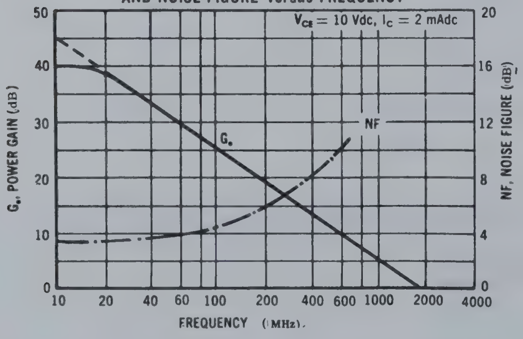
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 10 μAdc, I_E = 0				Vdc
		2N3287, 2N3288	40	—	—	
		2N3289, 2N3290	30	—	—	
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 10 μAdc, V_{BE} = 0				Vdc
		2N3287, 2N3288	40	—	—	
		2N3289, 2N3290	30	—	—	
Collector-Emitter Breakdown Voltage	BVCEO	I_C = 2.0 mAdc, I_B = 0				Vdc
		2N3287, 2N3288	20	—	—	
		2N3289, 2N3290	15	—	—	
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 10 μAdc, I_C = 0	3.0	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc All Types	—	—	.010	μAdc
		V_{CB} = 15 Vdc, T_A = 150°C 2N3287, 2N3288	—	—	3.0	
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc				—
		2N3287, 2N3288	15	—	100	
		2N3289, 2N3290	10	—	150	
Collector-Emitter Saturation Voltage	$V_{CE\ (sat)}$	I_C = 5 mAdc, I_B = 0.5 mAdc				Vdc
		2N3287, 2N3288	—	—	0.3	
		2N3289, 2N3290	—	—	0.4	
Base-Emitter Saturation Voltage	$V_{BE\ (sat)}$	I_C = 5 mAdc, I_B = 0.5 mAdc				Vdc
		2N3287, 2N3288	—	—	0.9	
		2N3288, 2N3290	—	—	1.0	
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz				—
		2N3287, 2N3288	15	—	150	
		2N3289, 2N3290	10	—	200	
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz (Note 1)				pF
		2N3287	—	0.9	1.1	
		2N3288 thru 2N3290	—	1.2	1.5	
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc, f = 31.8 MHz				ps
		2N3287, 2N3288	3.0	8.0	15	
		2N3289, 2N3290	3.0	8.0	20	
Current Gain - Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 2 mAdc				MHz
		2N3287, 2N3288	350	600	1200	
		2N3289, 2N3290	300	500	1200	
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mAdc	—	2000	—	MHz
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz				dB
		All Types	17	—	24	
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz				dB
		2N3287, 2N3288	—	4.9	6.0	
		2N3289, 2N3290	—	6.0	7.0	
Power Gain (AGC)	G_e	V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200 MHz (Note 2)				dB
		2N3287	—	—	0	
		2N3289	—	—	+5	
		2N3288, 2N3290	—	0	—	

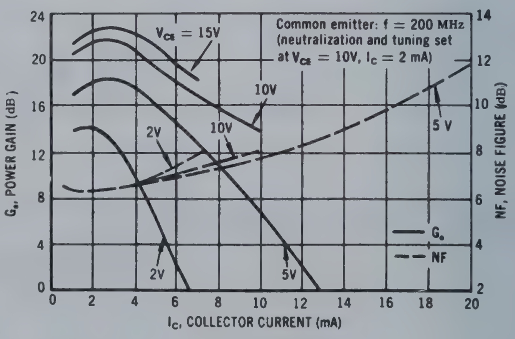
Note 1. C_{ob} is measured in guarded circuit such that the can capacitance is not included.

Note 2. AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc, I_C = 2 mAdc operation.

NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT



2N3291 thru 2N3294 (SILICON)

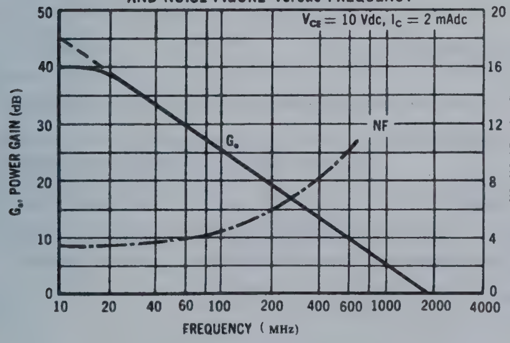
CASE 20
(TO-72)

NPN silicon annular transistor for TV and FM mixer, RF and IF amplifier and general-purpose, low-noise, high-gain amplifier applications.

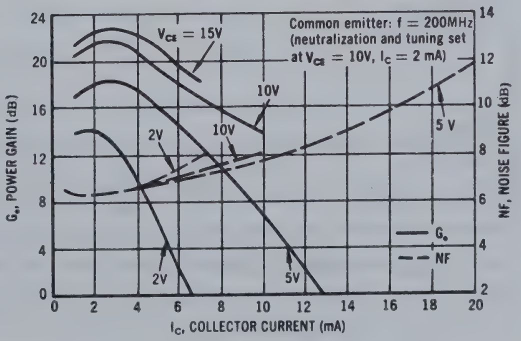
MAXIMUM RATINGS

Rating	Symbol	2N3291 2N3292	2N3293 2N3294	Unit
Collector - Base Voltage	V_{CB}	25	20	Volts
Collector - Emitter Voltage	V_{CES}	25	20	Volts
Emitter - Base Voltage	V_{EB}	3.0	3.0	Volts
Collector Current	I_C	50	50	mA
Power Dissipation at 25°C Case Above 25°C derate 1.71 mW/°C	P_D	300	300	mW
Power Dissipation at 25°C Amb. Above 25°C derate 1.14 mW/°C	P_D	200	200	mW
Junction Temperature	T_J	+200	+200	°C
Storage Temperature Range	T_{stg}	← -65 to +200 →		°C

NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT



ELECTRICAL CHARACTERISTICS ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 25 μAdc, V_{BE} = 0 2N3291, 2N3292 2N3293, 2N3294	 25 20	 35 30	 — —	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0	—	.01	0.1	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	—	—	100	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc	10	—	—	—
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz	10	—	200	—
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz , Note 1	—	1.0	2.0	pF
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 100 MHz	2.5	6.0	12	—
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc f = 31.8 MHz	—	15	30	ps
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mA	—	2000	—	MHz

2N3291

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	16	20	24	dB
Noise Figure	NF		—	6.0	8.0	dB
Power Gain (AGC)	G_e	Note 2 V_{CE} = 5 Vdc, I_C = 20 mAdc f = 200 MHz	—	—	0	dB

2N3292

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 200 MHz	16	20	24	dB
Noise Figure	NF		—	7.0	9.0	dB
Power Gain (AGC)	G_e	Note 2 V_{CE} = 5 Vdc, I_C = 20 mAdc f = 200 MHz	—	0	—	dB

2N3293

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Output	P_{out}	V_{EE} = -11 Vdc, f = 257 MHz	2.0	—	—	mW

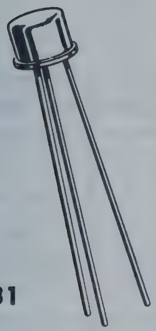
2N3294

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 200 MHz	14	—	—	dB
Noise Figure	NF		—	7.0	—	dB

Note 1. C_{ob} is measured in guarded circuit such that the can capacitance is not included.

Note 2. AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc, I_C = 2 mAdc operation.

2N3295 (SILICON)



CASE 31
(TO-5)

Collector connected to case

NPN silicon annular Star transistor for linear amplifier applications from 2.0 to 100 MHz.

MAXIMUM RATINGS*

Rating	Symbol	Rating	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current (Continuous)	I_C	250	mAdc
Base Current (Continuous)	I_B	50	mAdc
Total Device Dissipation (25°C Case Temperature) Derate above 25°C	P_D	2.0 13.3	Watts mW/°C
Total Device Dissipation (25°C Ambient Temperature) Derate above 25°C	P_D	0.8 5.33	Watts mW/°C
Junction Temperature Range	T_J	-65 to 175	°C
Storage Temperature Range	T_{stg}	-65 to 175	°C

* The maximum ratings as given for DC conditions can be exceeded on a pulse basis. See Electrical Characteristics.

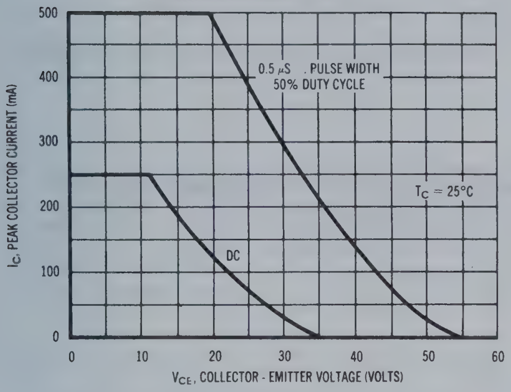
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Rating	Min	Typ	Max	Unit
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0 V_{CE} = 50Vdc, V_{BE} = 0, T_C = 175°C	-- --	-- --	100 500	μ Adc μ Adc
Collector Cutoff Current	I_{CBO}	V_{CB} = 50Vdc, I_E = 0	--	--	0.1	μ Adc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 5 Vdc, I_C = 0	--	--	100	μ Adc
DC Current Gain	h_{FE}	I_C = 10mAdc, V_{CE} = 10Vdc	20	--	60	--
		I_C = 150mAdc, V_{CE} = 10Vdc (1)	20	--	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 150mAdc, I_B = 15mAdc	--	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 150mAdc, I_B = 15mAdc	--	--	2.0	Vdc
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$ (1)	I_C = 100mA, R_{BE} = 0	30	--	--	Volts
Collector-Emitter Open Base Sustain Voltage	$V_{CEO(sus)}$ (1)	I_C = 100mA, I_B = 0	20	--	--	Volts
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10Vdc, I_C = 10mAdc, f=50 MHz	4.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 10Vdc, I_E = 0, f = 100 kHz	--	--	8.0	pF
Power Input (PEP) (Note 1)	P_{in}	P_{out} = 0.3 Watts PEP (0.15 W rms) f = 30MHz, V_{CE} = 15.0Vdc $I_{C(max)}$ = 40mA	--	--	12	mW
Power Gain	G_e		14	17	--	dB
Intermodulation Distortion Ratio	I_m		30	32	--	dB
Efficiency	η		25	30	--	%

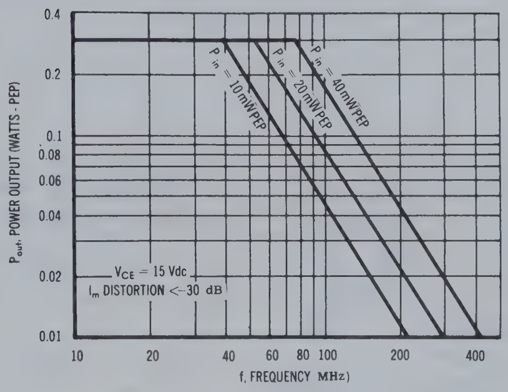
(1) Pulse Test: Pulse Width = 100 μs, Duty Cycle = 2 %

Note 1. PEP. Peak Envelope Power

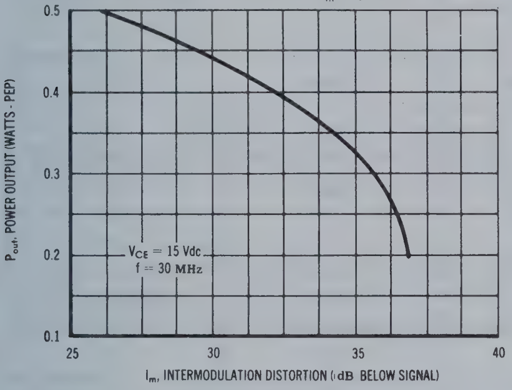
2N3295 (Continued)



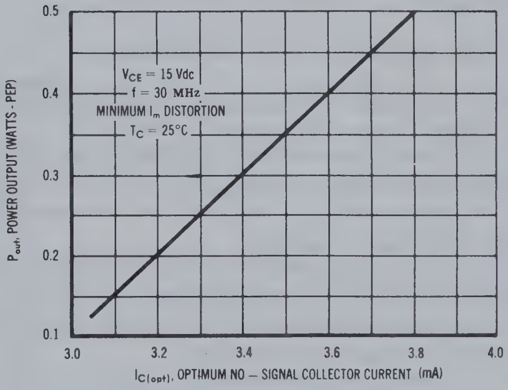
SAFE OPERATING AREA



POWER OUTPUT versus FREQUENCY

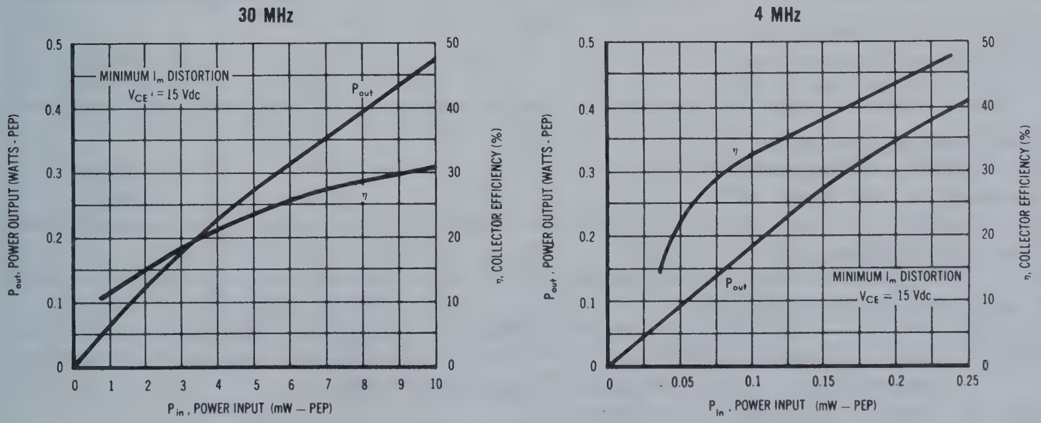


MAXIMUM POWER OUTPUT FOR GIVEN I_m DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS

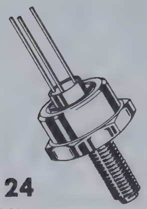
OUTPUT CHARACTERISTICS versus POWER INPUT



30 MHz

4 MHz

2N3296 (SILICON)



CASE 24
(TO-102)
Collector connected to case;
stud isolated from case

NPN silicon annular transistor for linear amplifier applications from 2 to 100 MHz.

MAXIMUM RATINGS (Note 1)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current (Continuous)	I_C	700	mAdc
Base Current (Continuous)	I_B	100	mAdc
RF Input Power (Note 2)	P_{in}	1.0	Watt (PEP)
RF Output Power (Note 2)	P_{out}	5.0	Watts (PEP)
Total Device Dissipation (25°C Case Temperature) Derating Factor above 25°C	P_D	6.0 40	Watts mW/°C
Total Device Dissipation at (25°C Ambient Temperature) Derating Factor above 25°C	P_D	0.7 4.67	Watts mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

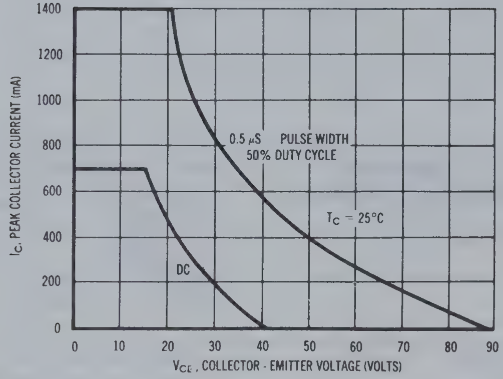
Note 1: The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.
Note 2: PEP = Peak Envelope Power.

ELECTRICAL CHARACTERISTICS

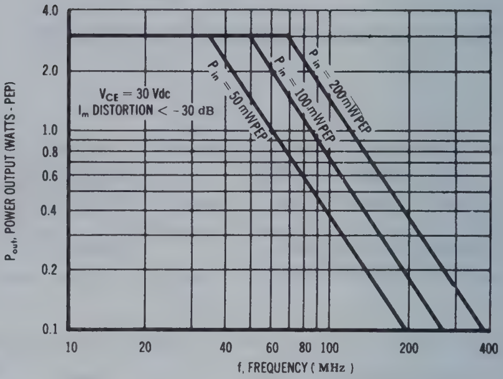
Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$(1)	I_C = 0.200A, R_{BE} = 0	85	120	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$(1)	I_C = 0.200A, I_B = 0	40	--	--	Volts
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0	--	--	100	μAdc
		V_{CE} = 50Vdc, V_{BE} = 0, T_C = +175°C	--	--	500	
Collector-Cutoff Current	I_{CBO}	V_{CB} = 50Vdc, I_E = 0	--	--	0.1	μAdc
Emitter-Cutoff Current	I_{EBO}	V_{EB} = 3Vdc, I_C = 0	--	--	100	μAdc
DC Current Gain	h_{FE}	V_{CE} = 2.0Vdc, I_C = 40mAdc	5.0	--	50	--
		V_{CE} = 2.0Vdc, I_C = 400mAdc	5.0	--	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 400mAdc, I_B = 80mAdc	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	I_C = 400mAdc, I_B = 80mAdc	--	--	2.0	Vdc
AC Current Gain	$\|h_{fe}\|$	V_{CE} = 2.0Vdc, I_C = 40mAdc, f = 50MHz	2.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 25Vdc, I_E = 0, f = 100kHz	--	--	20	pF
Power Input (PEP) (Note 2)	P_{in}	P_{out} = 3.0 Watts (PEP)(1.5 W rms) V_{CE} = 30 Volts, f = 30MHz $I_{C(max)}$ = 125mA	--	--	75	mW
Power Gain	G_e		16	19	--	dB
Intermodulation Distortion Ratio	I_m		30	35	--	dB
Efficiency	η		40	48	--	%

(1) Pulse Test. Pulse Width = 100 μsec. Duty Cycle = 2%.
Note 2 PEP. Peak Envelope Power.

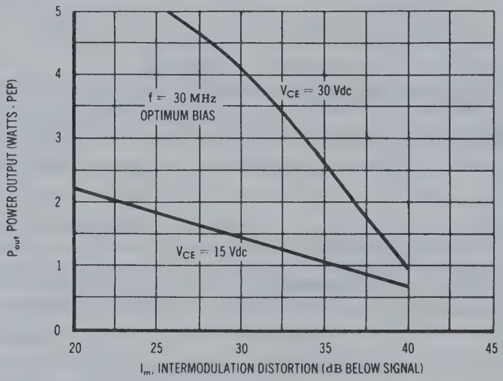
SAFE OPERATING AREA



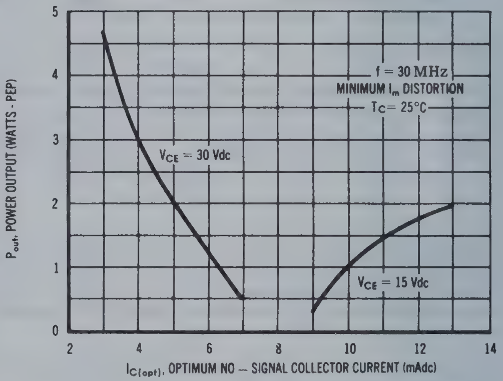
POWER OUTPUT versus FREQUENCY



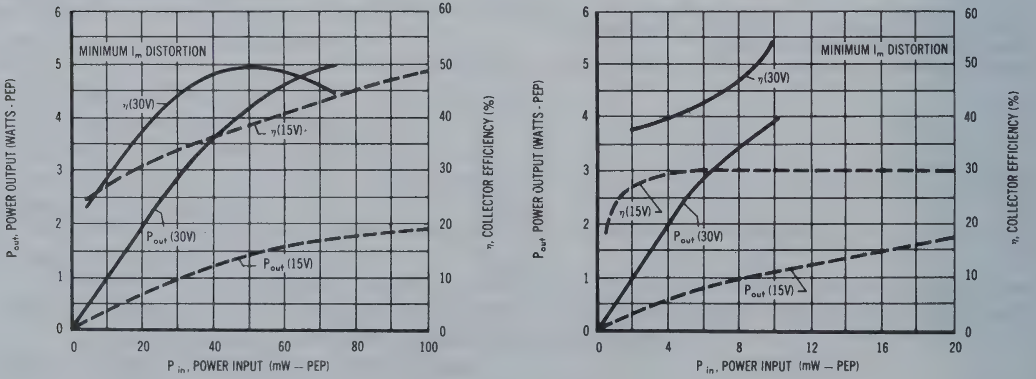
MAXIMUM POWER OUTPUT FOR GIVEN I_m DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS

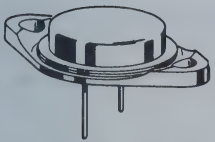


OUTPUT CHARACTERISTICS versus POWER INPUT


30 MHz

4 MHz

2N3297 (SILICON)



CASE 1
(TO-3)

Collector connected to case

NPN silicon annular transistor for linear amplifier applications for 2 to 100 MHz.

MAXIMUM RATINGS *

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current (Continuous)	I_C	1.5	Adc
Base-Current (Continuous)	I_B	500	mAdc
Power Input (PEP)	P_{in}	5.0	Watts (PEP)
Power Output (PEP)	P_{out}	20.0	Watts (PEP)
Total Device Dissipation @ 25°C Case Temperature Derating Factor above 25°C	P_D	25.0 167	Watts mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See electrical characteristics

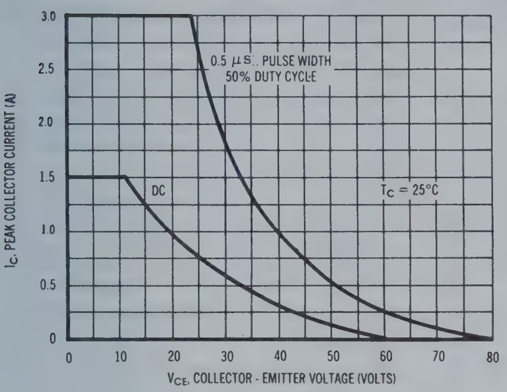
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$[1]	I_C = 0.250A, R_{BE} = 0	80	100	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$[1]	I_C = 0.250A, I_B = 0	40	--	--	Volts
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0 V_{CE} = 50Vdc, V_{BE} = 0, T_C = +175°C	-- --	-- --	0.5 1.0	mAdc
Collector-Cutoff Current	I_{CBO}	V_{CB} = 50Vdc, I_E = 0	--	--	1.0	μAdc
Emitter-Cutoff Current	I_{EBO}	V_{EB} = 3Vdc, I_C = 0	--	--	100	μAdc
DC Current Gain	h_{FE}	I_C = 400mAdc, V_{CE} = 2Vdc I_C = 1Adc, V_{CE} = 2Vdc	6.0 2.5	-- --	60 --	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 1Adc, I_B = 500mAdc	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	I_C = 1Adc, I_B = 500mAdc	--	--	2.0	Vdc
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 2Vdc, I_C = 400mAdc, f = 50MHz	2.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 25Vdc, I_E = 0, f = 100kHz	--	--	60	pF
Power Input (PEP) Note 2	P_{in}	P_{out} = 12 Watts PEP (6.0W rms) V_{CE} = 30 Volts, f = 30MHz $I_{C(max)}$ = 0.50 Amp	--	--	1.2	Watts PEP
Power Gain	G_e		10	13	--	dB
Intermodulation Distortion Ratio	I_m		30	33	--	dB
Efficiency	η		40	45	--	%

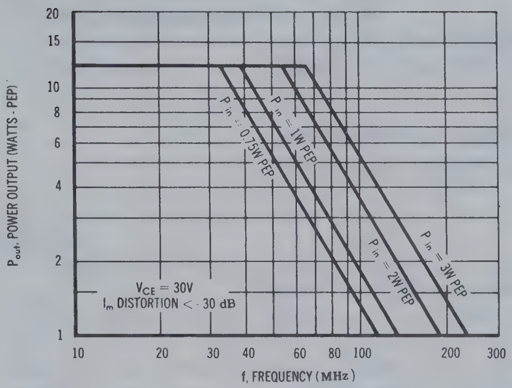
[1] Pulse Test: Pulse Width = 100μs, Duty Cycle = 2 %

Note 2. PEP. Peak Envelope Power

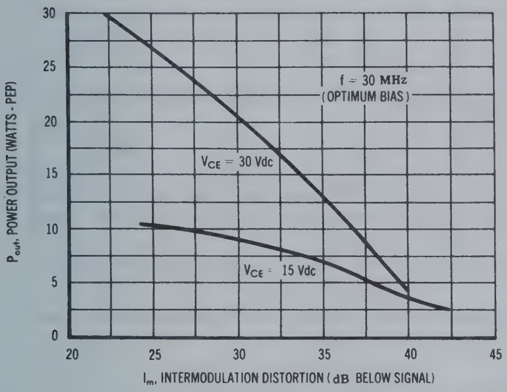
SAFE OPERATING AREA



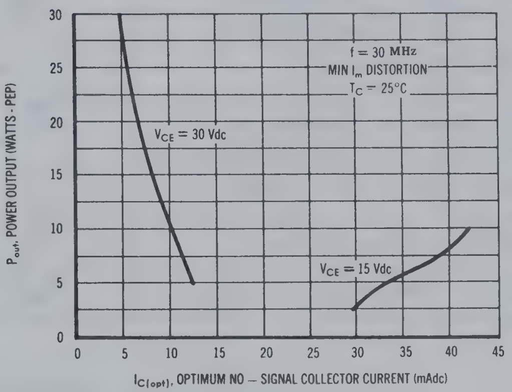
POWER OUTPUT versus FREQUENCY



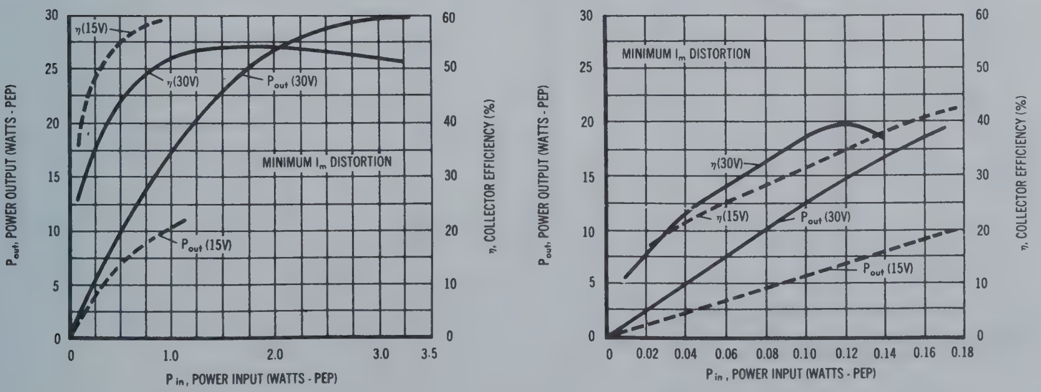
MAXIMUM POWER OUTPUT FOR GIVEN I_m DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS

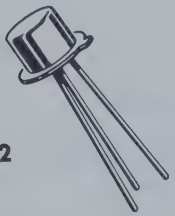


OUTPUT CHARACTERISTICS versus POWER INPUT


30 MHz

4 MHz

2N3298 (SILICON)



CASE 22
(TO-18)

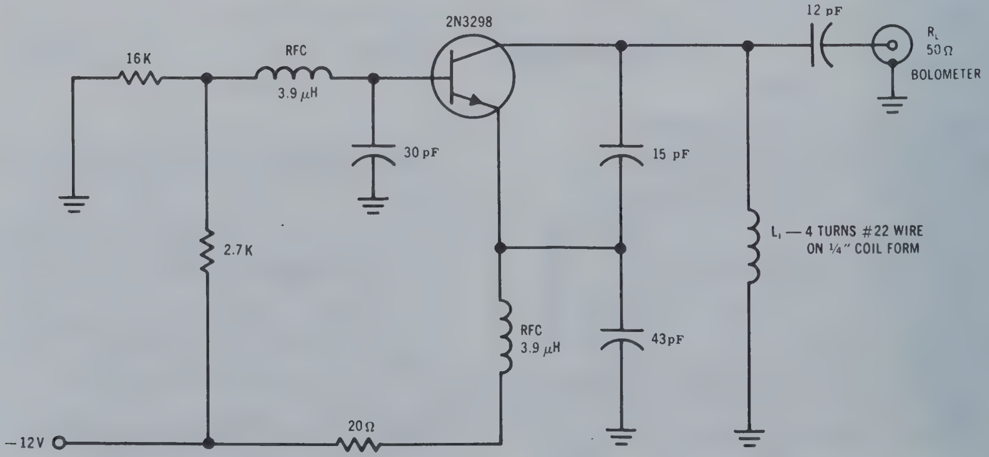
Collector connected to case

NPN silicon annular transistor for power oscillator applications to 150 MHz.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mA
Total Device Dissipation (25°C Case Temperature) Derate Above 25°C	P_D	1.0 6.67	Watt mW/°C
Total Device Dissipation (25°C Ambient Temperature) Derate Above 25°C 2mW/°C	P_D	0.3 2.0	Watt mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

80 MHz OSCILLATOR POWER OUTPUT TEST CIRCUIT

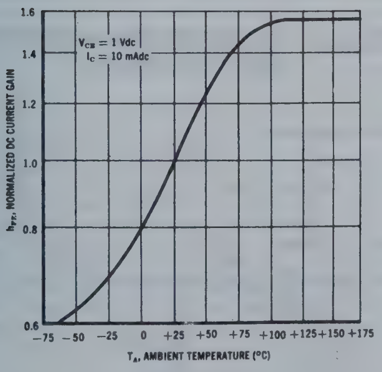

2N3298
16K
RFC
3.9 μH
30 pF
2.7 K
12 pF
R_L
50 Ω
BOLOMETER
15 pF
43pF
RFC
3.9 μH
L_1 — 4 TURNS #22 WIRE
ON 1/4" COIL FORM
20 Ω
–12 V

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

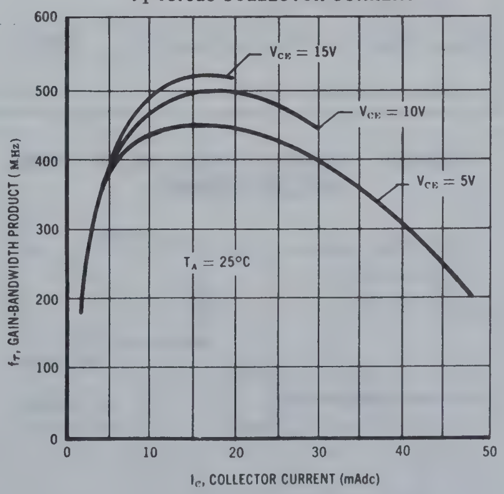
Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C=25 μAdc, V_{BE}=0	25	35	-	Vdc
Collector-Emitter Open Base Sustaining Voltage	$BV_{CEO(sus)}$ (1)	I_C=10mA, I_B=0	15	24	-	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB}=10 Vdc, I_E=0 V_{CB}=10 Vdc, I_E=0, T_A=150°C	- -	0.01 10	0.5 50	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB}=3 Vdc, I_C = 0	-	-	10	μAdc
DC Current Gain	h_{FE}	V_{CE}=1 Vdc, I_C=10 mAdc	60	90	120	-
AC Current Gain	$\|h_{fe}\|$	V_{CE}=10 Vdc, I_C=10mAdc, f=100 MHz	2.0	-	-	-
Collector Output Capacitance	C_{ob}	V_{CB}=10 Vdc, I_E=0, f=100 kHz	-	5.0	6.0	pF
Power Output	P_{out}	f=80 MHz V_{CC}=12 Vdc $I_{C(max)}$=20 mA	60	-	100	mW
Efficiency	η		25	40	-	%

(1) Pulse Width = 300 μs, Duty Cycle = 2%

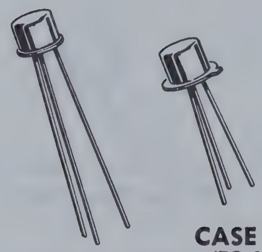
NORMALIZED DC CURRENT GAIN versus AMBIENT TEMPERATURE



f_T versus COLLECTOR CURRENT



2N3299 thru 2N3302 (SILICON)



CASE 31
(TO-5)
2N3299
2N3300

CASE 22
(TO-18)
2N3301
2N3302

Collector connected to case

NPN silicon annular transistors for high-speed switching circuits and DC to UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Emitter Voltage (Applicable 0 to 10 mAdc)	V_{CEO}	30		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	500		mAdc
Operating Junction Temperature Range	T_J	-65 to +200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		2N3299 2N3300	2N3301 2N3302	
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.8 4.56	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.2	1.8 10.3	Watts mW/°C

FIGURE 1 — SATURATED TURN-ON SWITCHING TIME TEST CIRCUIT

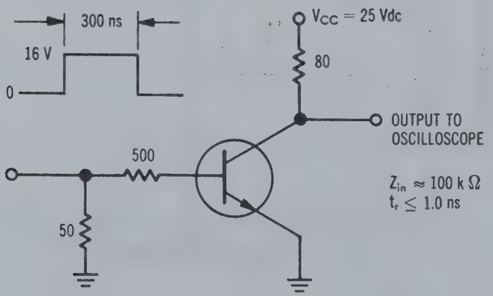
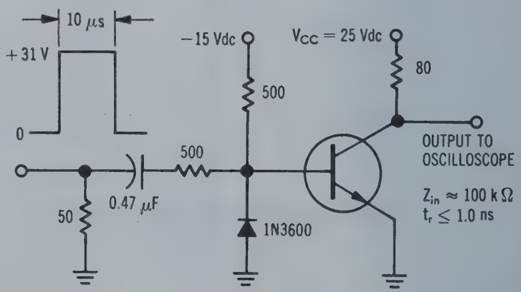

300 ns
16 V
0
V_{CC} = 25 Vdc
80
OUTPUT TO OSCILLOSCOPE
500
50
$Z_{in} \approx 100$ kΩ
$t_r \leq 1.0$ ns

FIGURE 2 — SATURATED TURN-OFF SWITCHING TIME TEST CIRCUIT


10 μs
+31 V
0
−15 Vdc
500
V_{CC} = 25 Vdc
80
500
0.47 μF
50
1N3600
OUTPUT TO OSCILLOSCOPE
$Z_{in} \approx 100$ kΩ
$t_r \leq 1.0$ ns

2N3299 thru 2N3302 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, V_{BE} = 0)	I_{CES}	-	0.01	μAdc
(V_{CE} = 50 Vdc, V_{BE} = 0, T_A = 150°C)		-	10	
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	10	nAdc
Base Current (V_{CE} = 50 Vdc, V_{BE} = 0)	I_B	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3299, 2N3301	h_{FE}	20	-	-
2N3300, 2N3302		35	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N3299, 2N3301		25	-	
2N3300, 2N3302		50	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) (1) 2N3299, 2N3301		35	-	
2N3300, 2N3302		75	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc) (1) 2N3299, 2N3301		20	-	
2N3300, 2N3302		50	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) (1) 2N3299, 2N3301		40	120	
2N3300, 2N3302		100	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) (1) 2N3299, 2N3301		20	-	
2N3300, 2N3302		50	-	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	0.22	Vdc
(I_C = 300 mAdc, I_B = 30 mAdc)		-	0.45	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	0.6	
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.1	Vdc
(I_C = 300 mAdc, I_B = 30 mAdc)		-	1.3	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	1.5	
Base-Emitter On Voltage (I_C = 150 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	20	pF
Turn-On Time (Figure 1) (V_{CC} = 25 Vdc, I_C ≈ 300 mAdc, I_{B1} ≈ 30 mAdc)	t_{on}	-	60	ns
Turn-Off Time (Figure 2) (V_{CC} = 25 Vdc, I_C ≈ 300 mAdc, I_{B1} = I_{B2} ≈ 30 mAdc)	t_{off}	-	150	ns

(1) Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%.

2N3303 (SILICON)

CASE 94

Collector connected to case

NPN silicon annular transistor designed for high-speed, high-current switching and driving applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current-Continuous	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.6 3.43	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.0 17.2	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	12	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.5 mAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_{CES}	-	100	μAdc
Base Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_B	-	100	μAdc

*Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2%

2N3303 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc)		20	-	
(I_C = 100 mAdc, V_{CE} = 0.5 Vdc) (1)		30	-	
(I_C = 300 mAdc, V_{CE} = 0.5 Vdc) (1)		30	120	
(I_C = 300 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C) (1)		10	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc) (1)		-	0.23	
(I_C = 300 mAdc, I_B = 30 mAdc) (1)		-	0.33	
(I_C = 300 mAdc, I_B = 30 mAdc, T_A = 125°C) (1)		-	0.50	
(I_C = 1 Adc, I_B = 100 mAdc) (1)		-	0.70	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.78	
(I_C = 100 mAdc, I_B = 10 mAdc) (1)		-	1.10	
(I_C = 300 mAdc, I_B = 30 mAdc) (1)		-	1.30	
(I_C = 1 Adc, I_B = 100 mAdc) (1)		-	2.1	
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product (I_C = 100 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	f_T	450	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	25	pF
Turn-On Time (Figure 1) ($V_{EB(off)} \approx$ 4 Vdc, $I_C \approx$ 1 Adc, $I_{B1} \approx$ 100 mAdc)	t_{on}	-	15	ns
Turn-Off Time (Figure 1) ($I_C \approx$ 1 Adc, $I_{B1} \approx I_{B2} \approx$ 100 mAdc)	t_{off}	-	25	ns
Storage Time (Figure 2) ($I_C \approx$ 100 mAdc, $I_{B1} \approx I_{B2} \approx$ 100 mAdc)	t_s	-	15	ns

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2%

FIGURE 1 – TURN-ON AND TURN-OFF TIME TEST CIRCUIT

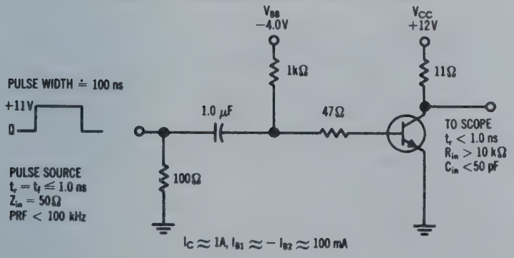
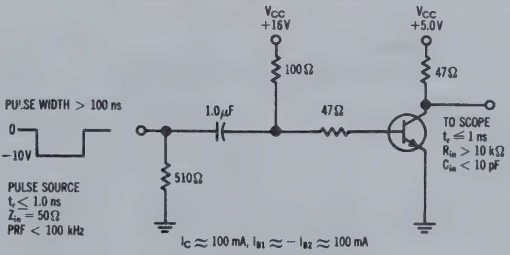

V_{BB}
−4.0V
V_{CC}
+12V
1kΩ
11Ω
PULSE WIDTH ≐ 100 ns
+11V
0
1.0 µF
47Ω
TO SCOPE
t_r < 1.0 ns
R_{in} > 10 kΩ
C_{in} < 50 pF
PULSE SOURCE
$t_r = t_f \leqq$ 1.0 ns
Z_{in} = 50Ω
PRF < 100 kHz
100Ω
$I_C \approx$ 1A, $I_{B1} \approx -I_{B2} \approx$ 100 mA

FIGURE 2 – STORAGE TIME TEST CIRCUIT


V_{CC}
+16V
V_{CC}
+5.0V
100Ω
47Ω
PULSE WIDTH > 100 ns
0
−10V
1.0µF
47Ω
TO SCOPE
$t_r \leqq$ 1 ns
R_{in} > 10 kΩ
C_{in} < 10 pF
PULSE SOURCE
$t_r \leq$ 1.0 ns
Z_{in} = 50Ω
PRF < 100 kHz
510Ω
$I_C \approx$ 100 mA, $I_{B1} \approx -I_{B2} \approx$ 100 mA

2N3304 (SILICON)

CASE 22
(TO-18)

Collector connected to case

PNP silicon annular transistor designed for low-level, high-speed switching applications.

MAXIMUM RATINGS

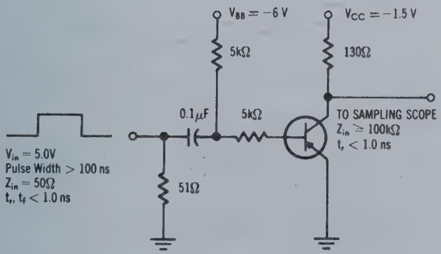
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	6.0	Vdc
Collector-Base Voltage	V_{CB}	6.0	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.72	mW mW/°C
Total Device Dissipation @ T_C = 100°C Derate above 100°C	P_D	500 5.0	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to+200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	6.0		Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	6.0	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	6.0	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 3 Vdc, V_{BE} = 0)	I_{CES}	—	0.01	μAdc
(V_{CE} = 3 Vdc, V_{BE} = 0, T_A = +125°C)		—	10	
Base Current (V_{CE} = 3 Vdc, V_{BE} = 0)	I_B	—	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 1 mAdc, V_{CE} = 0.5 Vdc)	h_{FE}	15	—	—
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc, T_A = -55°C)		12	—	
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		30	120	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)		20	—	
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)	$V_{CE(sat)}$	—	0.15	Vdc
(I_C = 10 mAdc, I_B = 1 mAdc, T_A = +125°C)		—	0.23	
(I_C = 10 mAdc, I_B = 1 mAdc)		—	0.16	
(I_C = 50 mAdc, I_B = 5 mAdc)		—	0.5	
Base-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)	$V_{BE(sat)}$	0.7	0.8	Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		0.8	1.0	
(I_C = 50 mAdc, I_B = 5 mAdc)		—	1.5	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	f_T	500	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	3.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	3.5	pF
Turn-On Time (Figure 1) (V_{CC} = 1.5 Vdc, V_{BB} = 6 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 0.5 mAdc)	t_{on}	—	60	ns
Turn-Off Time (Figure 1) (V_{CC} = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 0.5 mAdc)	t_{off}	—	60	ns
Charge-Storage Time (Figure 2) (I_C = 10 mAdc, V_{CC} = 3 Vdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	—	30	ns

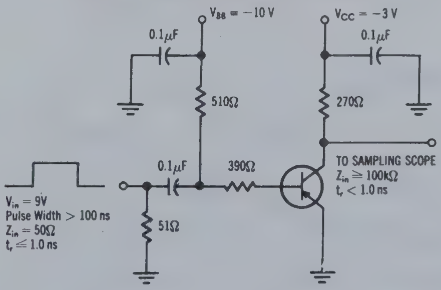
(1) Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

FIGURE 1 — TURN-ON & TURN-OFF TIME TEST CIRCUIT



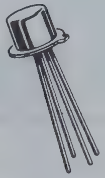
V_{BB} = −6 V
V_{CC} = −1.5 V
5kΩ
130Ω
0.1μF
5kΩ
TO SAMPLING SCOPE
Z_{in} ≥ 100kΩ
t_r < 1.0 ns
V_{in} = 5.0V
Pulse Width > 100 ns
Z_{in} = 50Ω
t_r, t_f < 1.0 ns
51Ω

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT



V_{BB} = −10 V
V_{CC} = −3 V
0.1μF
0.1μF
510Ω
270Ω
0.1μF
390Ω
TO SAMPLING SCOPE
Z_{in} ≥ 100kΩ
t_r < 1.0 ns
V_{in} = 9V
Pulse Width > 100 ns
Z_{in} = 50Ω
t_r ≤ 1.0 ns
51Ω

2N3307 (SILICON)
2N3308



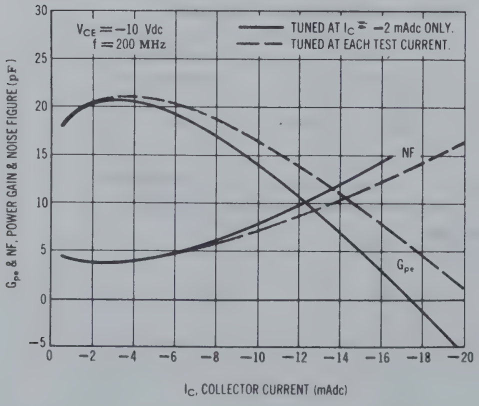
CASE 20
(TO-72)

PNP silicon annular transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

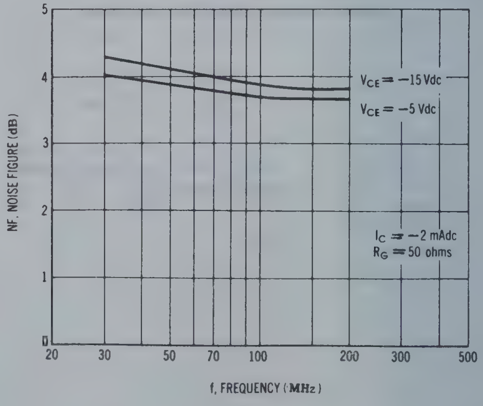
MAXIMUM RATINGS

Rating	Symbol	Value		Unit
		2N3307	2N3308	
Collector-Base Voltage	V_{CB}	40	30	Vdc
Collector-Emitter Voltage	V_{CES}	40	30	Vdc
Collector-Emitter Voltage	V_{CEO}	35	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0		Vdc
Collector Current	I_C	50		mAdc
Power Dissipation at T_C = 25°C Derate above 25°C	P_D	300 1.71		mW mW/°C
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	200 1.14		mW mW/°C
Junction Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

COMMON EMITTER AVERAGE SMALL POWER GAIN & NOISE FIGURE versus COLLECTOR CURRENT



NOISE FIGURE versus FREQUENCY



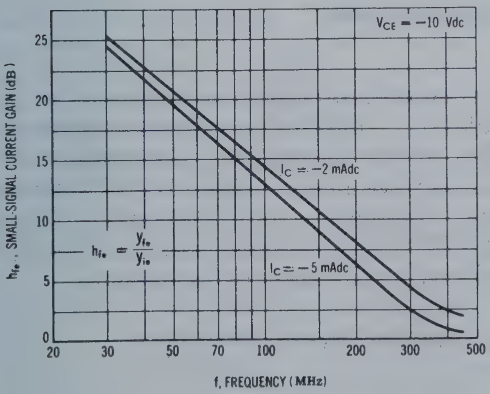
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions		Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 10 μAdc, I_E = 0	2N3307 2N3308	40 30	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 10 μAdc, V_{BE} = 0	2N3307 2N3308	40 30	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 2.0 mAdc, I_B = 0	2N3307 2N3308	35 25	— —	— —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 10 μAdc, I_C = 0	Both Types	3.0	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc V_{CB} = 15 Vdc, T = 150 °C	Both Types 2N3307	— —	0.001 0.5	0.010 3.0	μAdc
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc	2N3307 2N3308	40 25	— —	250 250	—
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 3 mAdc, I_B = 0.6 mAdc	Both Types	—	—	0.4	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 3 mAdc, I_B = 0.6 mAdc	Both Types	—	—	1.0	Vdc
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz	2N3307 2N3308	40 25	— —	250 250	—
Output Capacitance *	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz	2N3307 2N3308	— —	1.0 1.2	1.3 1.6	pF
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc, f = 31.8 MHz	2N3307 2N3308	2.0 2.0	— —	15 20	ps
Current Gain-Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 100 MHz	Both Types	300	—	1200	MHz
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mAdc	Both Types	—	2000	—	MHz
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	Both Types	17	—	24	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	2N3307 2N3308	— —	4.0 5.0	4.5 6.0	dB
Power Gain (AGC) * *	G_e	V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200 MHz	2N3307 2N3308	— —	— 0	0 —	dB

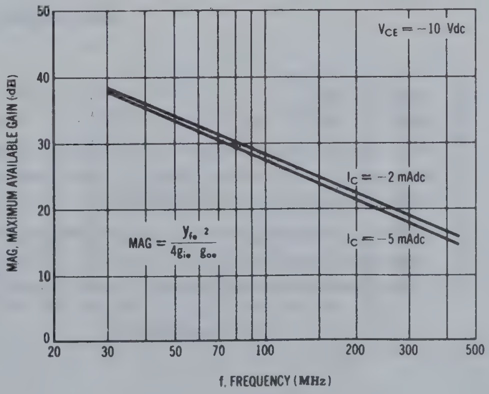
* C_{ob} is measured in guarded circuit such that the can capacitance is not included.

* * AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = -10 Vdc, I_C = -2 mAdc operation.

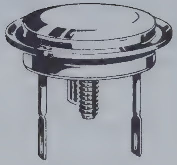
SMALL SIGNAL CURRENT GAIN versus FREQUENCY



MAXIMUM AVAILABLE GAIN versus FREQUENCY



2N3311 thru 2N3316 (GERMANIUM)



CASE 5
(TO-36)

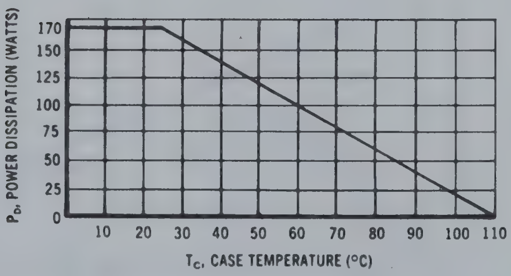
Collector connected to case

PNP germanium power transistors for high-power applications.

MAXIMUM RATINGS

Rating	Symbol	2N3311 2N3314	2N3312 2N3315	2N3313 2N3316	Unit
Collector-Base Voltage	V_{CB}	30	45	60	Volts
Collector-Emitter Voltage	V_{CES}	30	45	60	Volts
Collector-Emitter Voltage	V_{CEO}	20	30	40	Volts
Emitter-Base Voltage	V_{EB}	20	25	30	Volts
Collector Current (Continuous)	I_C	5.0			Amp
Power Dissipation at $T_C = 25^oC$	P_D	170			Watts
Junction Temperature Range	T_J	-65 to +110			^oC
Thermal Resistance	θ_{JC}	0.5			°C/W

POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 170 Watts at case temperatures of 25^oC and is 0 Watts at 110^oC with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110^o - Tc}{0.5}$$

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 500 mAdc, I_B = 0)	 2N3311, 2N3314 2N3312, 2N3315 2N3313, 2N3316	BV_{CEO}^*	 20 30 40	 - - -	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 300 mAdc, V_{BE} = 0)	 2N3311, 2N3314 2N3312, 2N3315 2N3313, 2N3316	BV_{CES}^*	 30 45 60	 - - -	Vdc
Collector Cutoff Current (V_{CE} = 10 Vdc, I_B = 0) (V_{CE} = 15 Vdc, I_B = 0) (V_{CE} = 20 Vdc, I_B = 0)	 2N3311, 2N3314 2N3312, 2N3315 2N3313, 2N3316	I_{CEO}	 - - -	 200 200 200	mAdc
Collector Cutoff Current (V_{CE} = 25 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C) (V_{CE} = 40 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C) (V_{CE} = 55 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C)	 2N3311, 2N3314 2N3312, 2N3315 2N3313, 2N3316	I_{CEX}	 - - -	 35 35 35	mAdc
Collector-Base Cutoff Current (V_{CB} = $V_{CB\ max}$) (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	 - -	 5.0 0.3	mAdc
Emitter-Base Cutoff Current (V_{BE} = $V_{BE\ max}$, I_C = 0)		I_{EBO}	 -	 4.0	mAdc

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain (I_C = 500 mAdc, V_{CB} = 2.0 Vdc) (I_C = 3.0 Adc, V_{CB} = 2.0 Vdc)	 2N3311 thru 2N3313 2N3314 thru 2N3316 2N3311 thru 2N3313 2N3314 thru 2N3316	h_{FE}	 - - 60 100	 150 250 120 200	-
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 300 mAdc)		$V_{CE(sat)}$	 -	 0.1	Vdc
Base-Emitter Voltage (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	 2N3311 thru 2N3313 2N3314 thru 2N3316	$V_{BE(on)}$	 - -	 0.6 0.5	Vdc

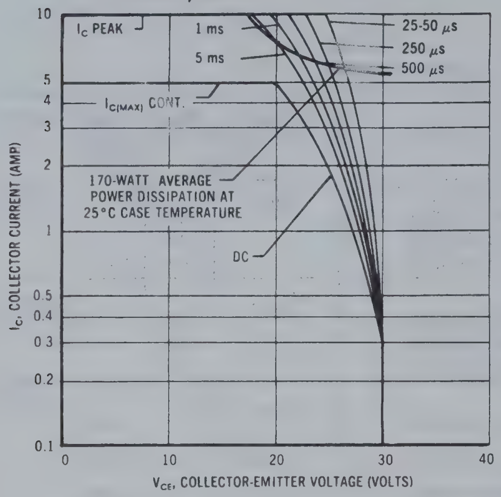
DYNAMIC CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Common Emitter Cutoff Frequency (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		$f_{\alpha e}$	 1.0	 -	kHz
Small Signal Current Gain (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc, f = 0.5 kHz)	 2N3311 thru 2N3313 2N3314 thru 2N3316	h_{fe}	 30 40	 90 120	-

*To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.

2N3311 thru 2N3316 (continued)

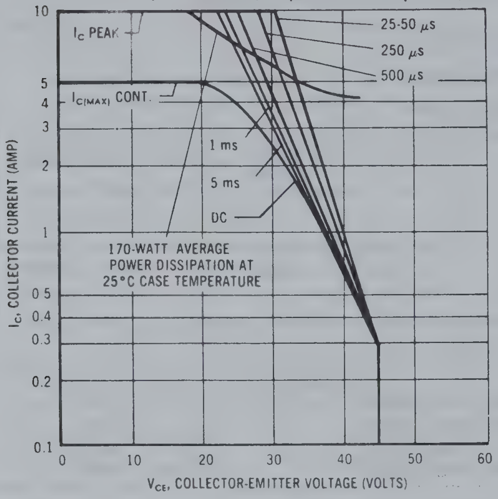
2N3311, 2N3314 (25 µsec to 5 msec pulse)



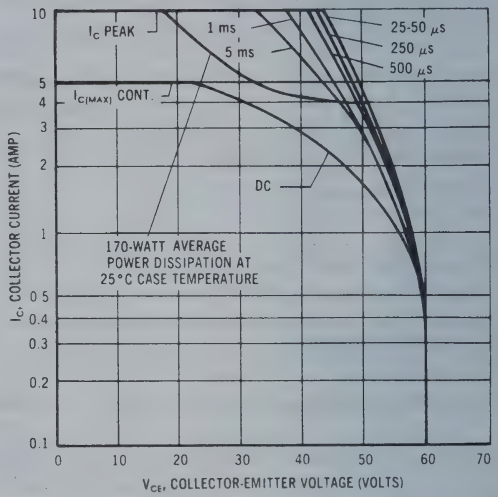
SAFE OPERATING AREA

The Safe Operating Area Curves indicate the I_C-V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the average power derating curve is also taken into consideration to insure operation below the maximum junction temperature.

2N3312, 2N3315 (25 µs to 5 ms pulse)

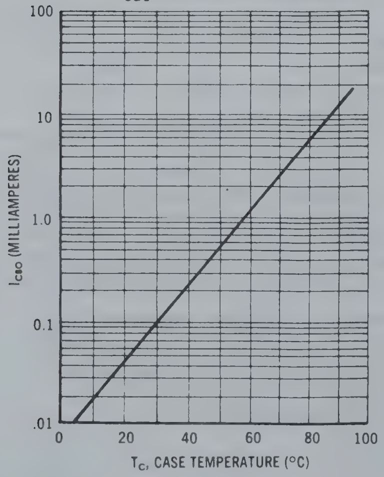


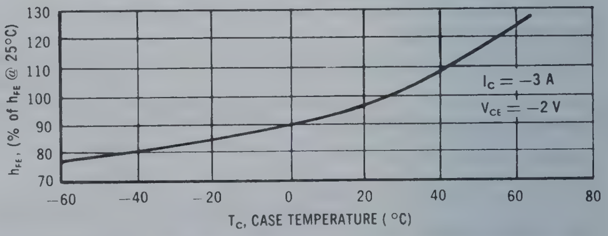
2N3313, 2N3316 (25 µs to 5 ms pulse)



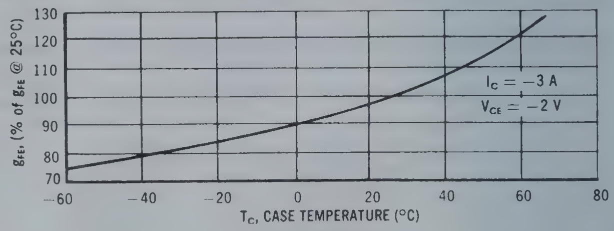
TEMPERATURE CHARACTERISTICS

I_{CBO} versus TEMPERATURE





DC TRANSCONDUCTANCE versus CASE TEMPERATURE



2N3323 (GERMANIUM)
2N3324
2N3325

PNP germanium epitaxial transistors for FM RF, IF, mixer and oscillator and AM RF, IF and converter applications.

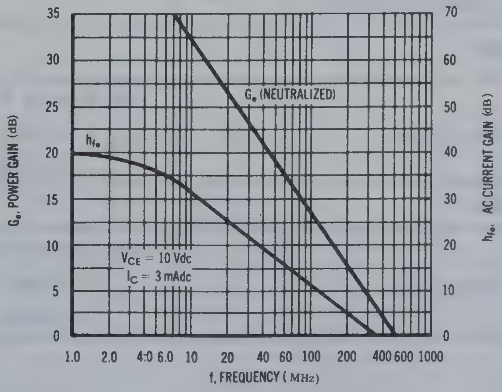
CASE 22
(TO-18)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	35	Vdc
Collector-Emitter Voltage	V_{CES}	35	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mA
Total Device Dissipation 25°C Case Temperature Derate Above 25°C	P_D	300 4.0	mW mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate Above 25°C	P_D	150 2.0	mW mW/°C
Junction Temperature	T_J	+100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C

POWER GAIN AND AC CURRENT GAIN versus FREQUENCY



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CER}	I_C = 100 μAdc, R_{BE} = 10K	35	40	--	Vdc
Collector-Emitter Current	I_{CES}	V_{CE} = 35 Vdc, V_{BE} = 0	--	--	100	μAdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0	--	0.5	10	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 2 Vdc, I_C = 0	--	--	100	μAdc
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C = 3 mAdc	30	--	200	--
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 1 kHz	30	--	225	--
Current-Gain — Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	200	--	600	MHz
Collector-Base Time Constant	$r_b'C_C$	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 31.8 MHz	--	50	100	ps
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0 f = 100 kHz	--	2.2	3.0	pF
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 3mAdc	--	500	--	MHz
Input Resistance, Parallel Equivalent	R_{ie}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 10 MHz	--	1200	--	ohms
Output Resistance, Parallel Equivalent	R_{oe}		--	11	--	kohms
Input Resistance, Parallel Equivalent	R_{ie}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	--	100	--	ohms
Output Resistance, Parallel Equivalent	R_{oe}		--	1.0	--	kohms

2N3323

Power Gain	G_e	Test Circuit Figure 1 V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	11	--	15	dB

2N3324

Power Gain	G_e	Test Circuit Figure 2 V_{CE} = 10 Vdc, I_C = 3 mAdc f = 10 MHz	24	--	31	dB

FIGURE 1: 100 MHz POWER GAIN TEST CIRCUIT — 2N3323

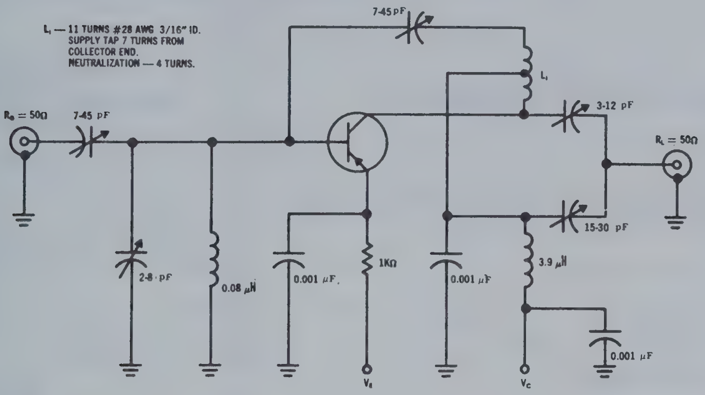
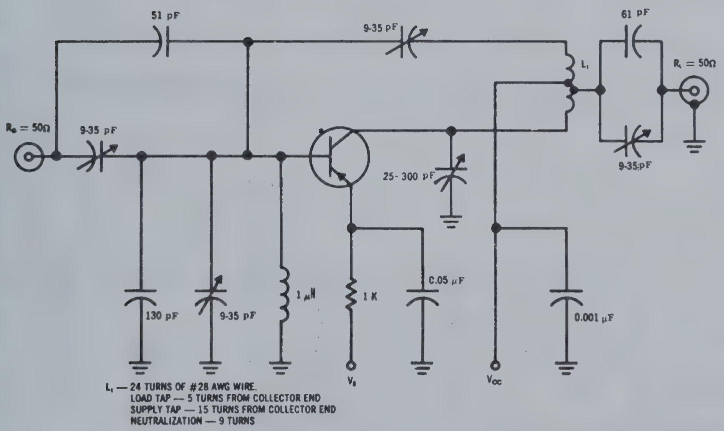

L₁ — 11 TURNS #28 AWG 3/16" ID.
SUPPLY TAP 7 TURNS FROM
COLLECTOR END.
NEUTRALIZATION — 4 TURNS.
7-45 pF
L₁
Rₛ = 50Ω
7-45 pF
3-12 pF
R_L = 50Ω
15-30 pF
2-8 pF
0.08 μH
0.001 μF
1KΩ
0.001 μF
3.9 μH
0.001 μF
V_B
V_C

FIGURE 2: 10 MHz POWER GAIN TEST CIRCUIT — 2N3324


51 pF
9-35 pF
61 pF
L₁
R_L = 50Ω
Rₛ = 50Ω
9-35 pF
25-300 pF
9-35 pF
C.05 μF
130 pF
9-35 pF
1 μH
1 K
0.001 μF
V_B
V_CC
L₁ — 24 TURNS OF #28 AWG WIRE.
LOAD TAP — 5 TURNS FROM COLLECTOR END
SUPPLY TAP — 15 TURNS FROM COLLECTOR END
NEUTRALIZATION — 9 TURNS

2N3330 (SILICON)

SILICON P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

Depletion Mode (Type A) Junction Field-Effect Transistor designed primarily for low-power audio-amplifier applications.

- High AC Input Resistance —
  Typically > 30 Megohms @ f = 1.0 kHz
- Drain and Source Interchangeable
- Active Elements Isolated from Case

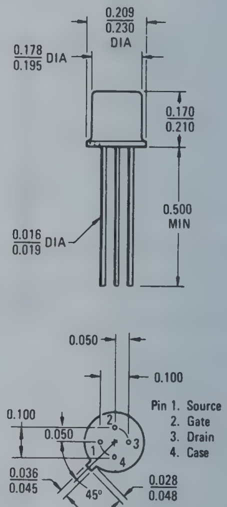
P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

(Type A)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Gate Voltage	V_{DG}	20	Vdc
Reverse Gate-Source Voltage	V_{GSR}	20	Vdc
*Gate Current	I_G	10	mAdc
*Total Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	300 2.0	mW mW/°C
*Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.100
0.050
2
1
3
4
0.036
0.045
45°
0.028
0.048
Pin 1. Source
2. Gate
3. Drain
4. Case

TO-72
CASE 20 (5)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_C = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	20	–	Vdc
Gate Reverse Current	I_{GSS}			nAdc
(V_{GS} = 10 Vdc, V_{DS} = 0)		–	10	
(V_{GS} = 10 Vdc, V_{DS} = 0, T_A = 150°C)		–	10	μAdc
Zero-Gate Voltage Drain Current (Note 1) (V_{DS} = –10 Vdc, V_{GS} = 0)	I_{DSS}	2.0	6.0	mAdc
ON CHARACTERISTICS				
Gate-Source Voltage (V_{DG} = –15 Vdc, I_D = 10 μAdc)	V_{GS}	–	6.0	Vdc
Drain-Source Resistance (I_D = 100 μAdc, V_{GS} = 0)	r_{DS}	–	800	Ohms
SMALL-SIGNAL CHARACTERISTICS				
Forward Transadmittance (Note 1)	$\|y_{fs}\|$			μmhos
(V_{DS} = –10 Vdc, I_D = 2.0 mAdc, f = 1.0 kHz)		1500	3000	
(V_{DS} = –10 Vdc, I_D = 2.0 mAdc, f = 10 MHz)		1350	–	
Output Admittance (V_{DS} = –10 Vdc, I_D = 2.0 mAdc, f = 1.0 kHz)	$\|y_{os}\|$	–	40	μmhos
Reverse Transfer Conductance (V_{DS} = –10 Vdc, I_D = 2.0 mAdc, f = 1.0 kHz)	$\|y_{rs}\|$	–	0.1	μmhos
Input Conductance (V_{DS} = –10 Vdc, I_D = 2.0 mAdc, f = 1.0 kHz)	$\|y_{is}\|$	–	0.2	μmhos
Input Capacitance (V_{DS} = –10 Vdc, V_{GS} = 1.0 Vdc, f = 1.0 MHz)	C_{iss}	–	20	pF
Common-Source Noise Figure (V_{DS} = –5.0 Vdc, I_D = 1.0 mAdc, R_G = 1.0 Megohm, f = 1.0 kHz)	NF	–	3.0	dB

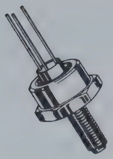
*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width $\leq$ 630 ms, Duty Cycle $\leq$10%.

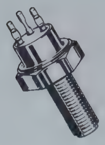
2N3375 (SILICON)
2N3553
2N3632
2N3961

*CASE 79
(TO-39)

2N3553


**CASE 24
(TO-102)

2N3961


***CASE 36
(TO-60)

2N3375
2N3632

* Collector Connected to Case

** Collector electrically connected to case; stud electrically isolated from case

*** Stud electrically isolated from case

NPN silicon RF Power transistors, optimized for large-signal power amplifier and driver applications to 400MHz, provide wide choice of power levels and guaranteed safe operating areas.

MAXIMUM RATINGS

Rating	Symbol	2N3375	2N3553	2N3632	2N3961	Unit
Collector-Emitter Voltage	V_{CEO}	← 40 →				Vdc
Collector-Base Voltage	V_{CB}	← 65 →				Vdc
Emitter-Base Voltage	V_{EB}	← 4.0 →				Vdc
Collector Current	I_C	1.5	1.0	3.0	1.0	Adc
Total Device Dissipation @ T_C = 25°C	P_D	11.6	7.0	23	10	Watts
Derate above 25°C		66.4	40	131	57.2	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →				°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.25 mAdc, I_C = 0)	2N3632	BV_{EBO}	4.0	-	Vdc
(I_E = 0.1 mAdc, I_C = 0)	2N3375, 2N3553		4.0	-	
(I_E = 1.0 mAdc, I_C = 0)	2N3961		4.0	-	
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	2N3375, 2N3553	I_{CEO}	-	0.1	mAdc
	2N3632		-	0.25	
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 200°C)	2N3375, 2N3553	I_{CEX}	-	5.0	mAdc
	2N3632		-	10	
(V_{CE} = 65 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N3375, 2N3553		-	1.0	
	2N3632		-	5.0	
Collector Cutoff Current (V_{CB} = 28 Vdc, I_E = 0, T_A = 150°C)	2N3961	I_{CBO}	-	5.0	mAdc
(V_{CB} = 65 Vdc, I_E = 0)	2N3632		-	0.5	
	2N3961		-	1.0	
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	2N3375, 2N3553	I_{EBO}	-	0.1	mAdc
	2N3632		-	0.25	

* Pulsed thru 25 mH inductor (See Figures 5 and 6).

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 250 mAdc, V_{CE} = 5.0 Vdc)	2N3375, 2N3553, 2N3632		10	-	-	
(I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)	2N3632		5.0	-	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 250 mAdc, I_B = 50 mAdc)	2N3553		-	-	1.0	
(I_C = 500 mAdc, I_B = 100 mAdc)	2N3375, 2N3632		-	-	1.0	
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 5.0 Adc)	2N3632	$V_{BE(sat)}$	-	-	1.5	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product		f_T				MHz
(I_C = 100 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	2N3553		-	500	-	
(I_C = 125 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	2N3961		350		-	
(I_C = 150 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	2N3375		-	500	-	
	2N3632		-	400	-	
Output Capacitance		C_{ob}				pF
(V_{CB} = 28 Vdc, I_E = 0, f = 100 kHz)	2N3961		-	8.0	10	
(V_{CB} = 30 Vdc, I_E = 0, f = 100 kHz)	2N3375, 2N3553		-	8.0	10	
	2N3632		-	16	20	

FUNCTIONAL TESTS

2N3375

Power Input	Test Circuit Figure 7 (V_{CE} = 28 Vdc, P_{out} = 7.5 Watts, f = 100 MHz)	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	8.75	-	-	dB
Collector Efficiency		η	65	-	-	%
Power Input	Test Circuit Figure 8 (V_{CE} = 28 Vdc, P_{out} = 3.0 Watts, f = 400 MHz)	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	4.77	-	-	dB
Collector Efficiency		η	40	-	-	%

2N3553

Power Input	Test Circuit Figure 9 (V_{CE} = 28 Vdc, P_{out} = 2.5 Watts, f = 175 MHz)	P_{in}	-	-	0.25	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	10	-	-	dB
Collector Efficiency		η	50	-	-	%

2N3632

Power Input	Test Circuit Figure 10 (V_{CE} = 28 Vdc, P_{out} = 13.5 Watts, f = 175 MHz)	P_{in}	-	-	3.5	Watts
Common-Emitter Amplifier Power Gain		G_{pe}	5.86	-	-	dB
Collector Efficiency		η	70	-	-	%

2N3961

Power Input	Test Circuit Figure 11 (V_{CE} = 12.5 Vdc, P_{out} = 2.0 Watts, R_S = 50 ohms, R_L = 50 ohms, f = 135 MHz)	P_{in}	-	-	0.5	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	6.0	-	-	dB
Collector Efficiency		η	60	-	-	%
Power Input	Test Circuit Figure 12 (V_{CE} = 28 Vdc, P_{out} = 4.0 Watts, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz)	P_{in}	-	-	0.5	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	9.0	-	-	dB
Collector Efficiency		η	60	-	-	%

POWER OUTPUT versus FREQUENCY

COMMON EMITTER — V_{CE} = 28 Vdc, T_C = 25°C

FIGURE 1 – 2N3375

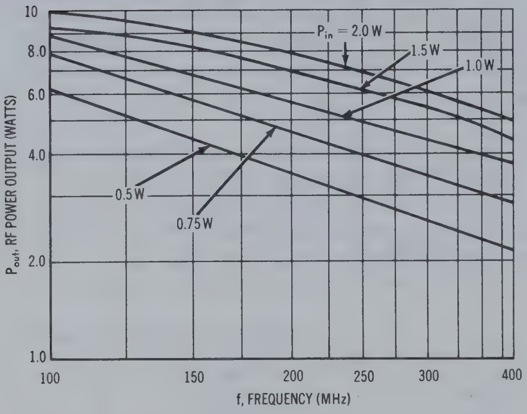


FIGURE 2 – 2N3553

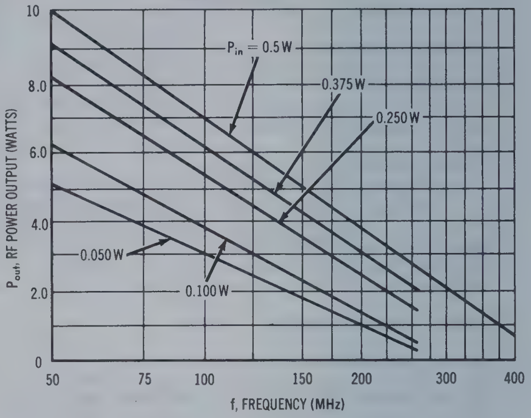


FIGURE 3 – 2N3632

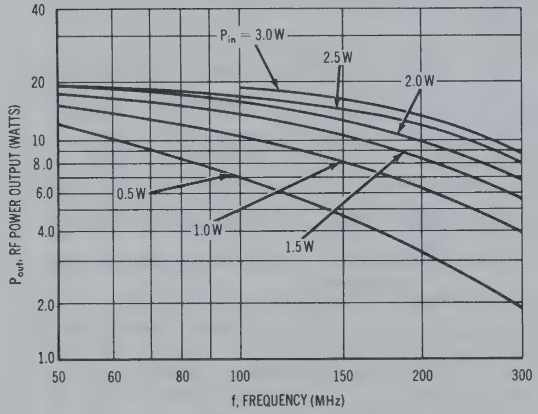
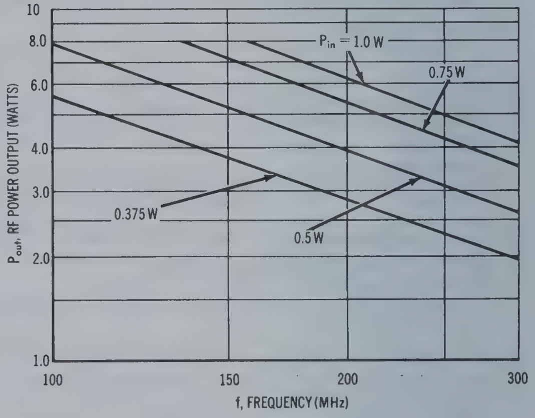


FIGURE 4 – 2N3961



$BV_{CEO(sus)}$ PULSE TEST CIRCUITS

FIGURE 5 – 2N3375, 2N3553, 2N3632

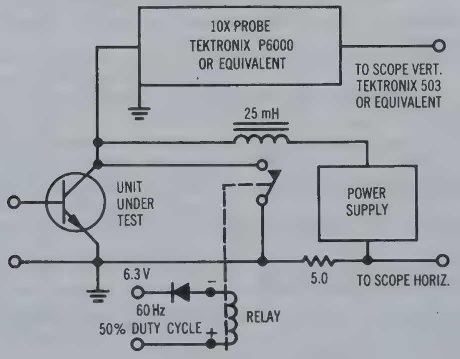
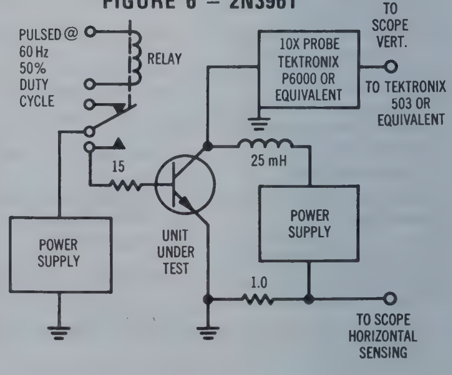

10X PROBE
TEKTRONIX P6000
OR EQUIVALENT
TO SCOPE VERT.
TEKTRONIX 503
OR EQUIVALENT
25 mH
UNIT
UNDER
TEST
POWER
SUPPLY
6.3 V
5.0
TO SCOPE HORIZ.
60 Hz
50% DUTY CYCLE
RELAY
–
+

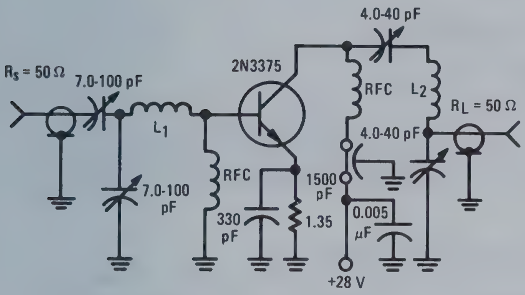
FIGURE 6 – 2N3961


PULSED @
60 Hz
50%
DUTY
CYCLE
RELAY
15
POWER
SUPPLY
UNIT
UNDER
TEST
10X PROBE
TEKTRONIX
P6000 OR
EQUIVALENT
TO
SCOPE
VERT.
TO TEKTRONIX
503 OR
EQUIVALENT
25 mH
POWER
SUPPLY
1.0
TO SCOPE
HORIZONTAL
SENSING

TEST CIRCUITS

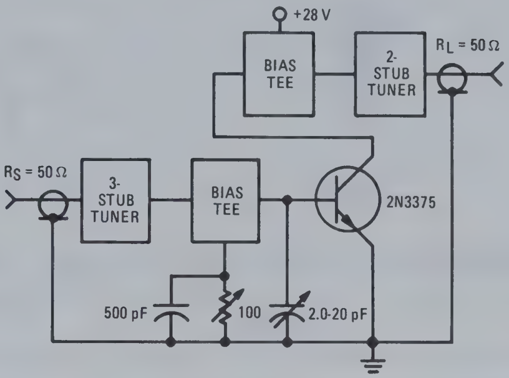
2N3375

FIGURE 7 – 100 MHz


Rs = 50 Ω
7.0-100 pF
L1
7.0-100 pF
2N3375
RFC
330 pF
1.35
4.0-40 pF
RFC
L2
RL = 50 Ω
4.0-40 pF
1500 pF
0.005 µF
+28 V

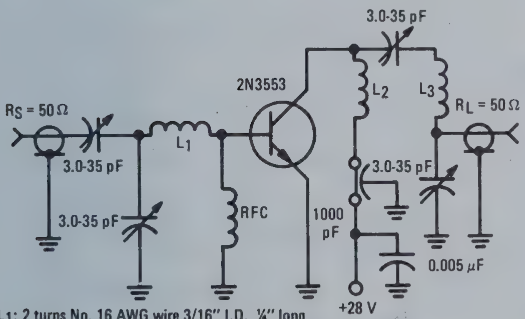
L_1: 3 turns No. 16 AWG wire ¼″ I.D., 5/16″ long
L_2: 5 turns No. 16 AWG wire 5/16″ I.D., 7/16″ long

FIGURE 8 – 400 MHz


+28 V
BIAS TEE
2-STUB TUNER
RL = 50 Ω
RS = 50 Ω
3-STUB TUNER
BIAS TEE
2N3375
500 pF
100
2.0-20 pF

2N3553

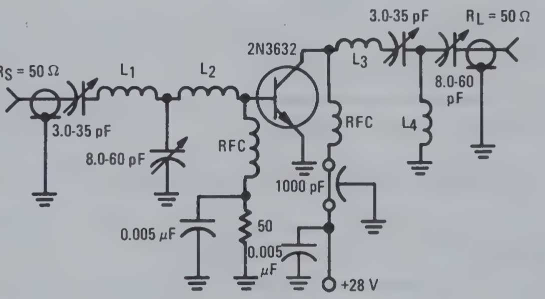
FIGURE 9 – 175 MHz


RS = 50 Ω
3.0-35 pF
3.0-35 pF
L1
2N3553
RFC
1000 pF
3.0-35 pF
L2
L3
RL = 50 Ω
3.0-35 pF
0.005 µF
+28 V

L_1: 2 turns No. 16 AWG wire 3/16″ I.D., ¼″ long
L_2: 2 turns No. 16 AWG wire 3/16″ I.D., ¼″ long
L_3: 3 turns No. 16 AWG wire 3/8″ I.D., 3/8″ long

2N3632

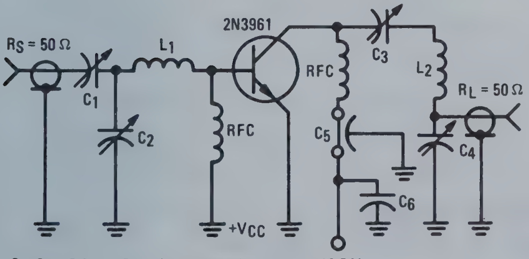
FIGURE 10 – 175 MHz


RS = 50 Ω
3.0-35 pF
L1
L2
8.0-60 pF
RFC
0.005 µF
50
0.005 µF
2N3632
3.0-35 pF
RL = 50 Ω
L3
RFC
1000 pF
L4
8.0-60 pF
+28 V

L_1, L_3: 4 turns No. 18 AWG wire ¼″ I.D. 3/16″ long
L_2: 1 turn No. 16 AWG wire ¼″ I.D., 3/16″ long
L_4: 2½ turns No. 16 AWG wire ¼″ I.D., ¼″ long

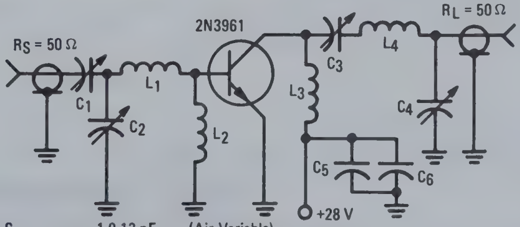
2N3961

FIGURE 11 – 135 MHz


RS = 50 Ω
C1
L1
C2
2N3961
RFC
+VCC
RFC
C3
C5
C6
L2
RL = 50 Ω
C4
+12.5 V

C_1, C_3 = 5.0-50 pF (Air Variable)
C_2 = 7.0-100 pF (Air Variable)
C_4 = 1.0-30 pF (Air Variable)
C_5 = 1000 pF (Disc Ceramic)
C_6 = 0.02 µF (Disc Ceramic)
L_1 = 3 turns No. 16 AWG wire, 5/16″ I.D., 5/16″ long
L_2 = 5 turns No. 16 AWG wire, 7/16″ I.D., 5/8″ long

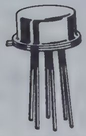
FIGURE 12 – 175 MHz


RS = 50 Ω
C1
C2
L1
L2
2N3961
L3
C3
C5
C6
+28 V
L4
C4
RL = 50 Ω

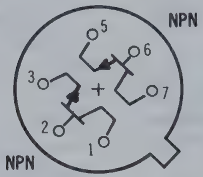
C_1	1.0-12 pF	(Air Variable)
C_2	1.0-30 pF	(Air Variable)
C_3	5.0-50 pF	(Air Variable)
C_4	7.0-75 pF	(Air Variable)
C_5	470 pF	(Disc Ceramic)
C_6	0.001 µF	(Disc Ceramic)
L_1, L_3, L_4	2 turns No. 18 AWG enameled wire ¼″ I.D., air wound 3/16″ long	
L_2	RFC, $Q_U < 1$	

2N3425 (SILICON)

Dual NPN silicon transistor designed for use as a high-frequency sense amplifier.



Case 654-04
TO-78

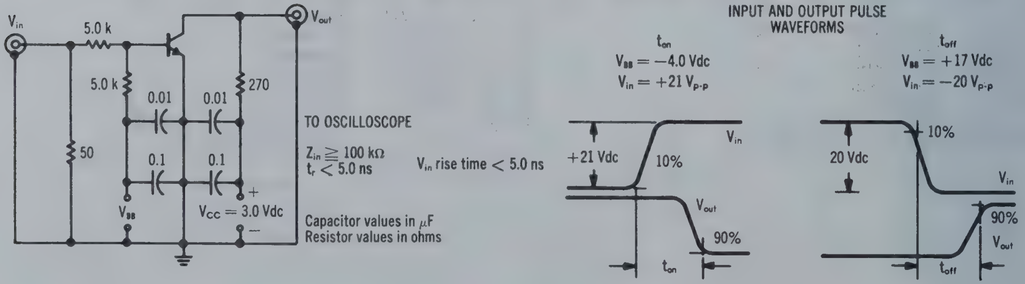

NPN
5
6
3
7
2
1
NPN

PINS 4 AND 8 OMITTED
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Emitter Voltage ($R_{BE} \leqq 10$ ohms)	V_{CER}	20		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.4	Watt
Derate above 25°C		1.72	2.28	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.75	1.5	Watt
T_C = 100°C		0.43	0.86	Watt
Derate above 25°C		4.3	8.55	mW/°C

FIGURE 1 — SWITCHING-TIME TEST CIRCUIT

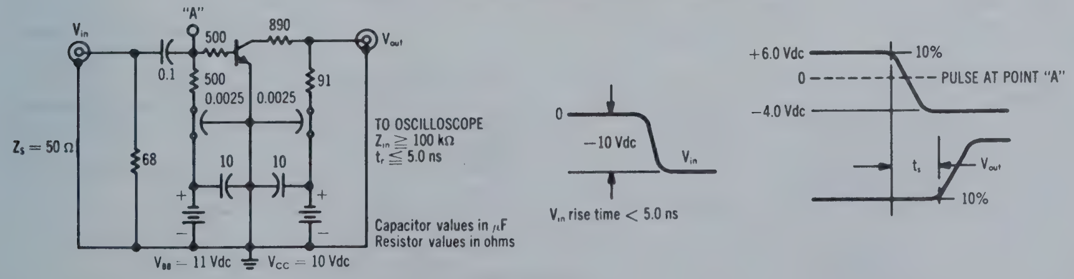

V_{in}
5.0 k
5.0 k
0.01
0.01
270
V_{out}
50
0.1
0.1
V_{BB}
+
V_{CC} = 3.0 Vdc
−
TO OSCILLOSCOPE
$Z_{in} \geqq 100$ kΩ
$t_r < 5.0$ ns
V_{in} rise time < 5.0 ns
Capacitor values in μF
Resistor values in ohms
INPUT AND OUTPUT PULSE WAVEFORMS
t_{on}
$V_{BB} = -4.0$ Vdc
$V_{in} = +21\ V_{p\text{-}p}$
+21 Vdc
10%
V_{in}
V_{out}
90%
t_{on}
t_{off}
$V_{BB} = +17$ Vdc
$V_{in} = -20\ V_{p\text{-}p}$
20 Vdc
10%
V_{in}
90%
V_{out}
t_{off}

ELECTRICAL CHARACTERISTICS (each side) ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) ($I_C = 10$ mAdc, $I_B = 0$)	$BV_{CEO(sus)}$	15	-	Vdc
Collector-Emitter Sustaining Voltage (1) ($I_C = 30$ mAdc, $R_{BE} \leqq 10$ ohms)	$BV_{CER(sus)}$	20	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 10$ µAdc, $I_E = 0$)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ µAdc, $I_C = 0$)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current ($V_{CE} = 20$ Vdc, $V_{EB(off)} = 0.25$ Vdc, $T_A = 125°C$)	I_{CEX}	-	15	µAdc
Collector Cutoff Current ($V_{CB} = 20$ Vdc, $I_E = 0$) ($V_{CB} = 20$ Vdc, $I_E = 0$, $T_A = 150°C$)	I_{CBO}	- -	0.025 15	µAdc
Emitter Cutoff Current ($V_{EB} = 4.0$ Vdc, $I_C = 0$)	I_{EBO}	-	0.2	µAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 0.5$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 10$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 10$ mAdc, $V_{CE} = 1.0$ Vdc, $T_A = -55°C$)	h_{FE}	12 30 12	- 120 -	-
Collector-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc) ($I_C = 7.0$ mAdc, $I_B = 0.7$ mAdc, $T_A = -55°C$ to $+125°C$)	$V_{CE(sat)}$	- -	0.4 0.5	Vdc
Base-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc) ($I_C = 7.0$ mAdc, $I_B = 0.7$ mAdc, $T_A = -55°C$)	$V_{BE(sat)}$	0.7 -	0.85 0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 140 kHz)	C_{ob}	-	6.0	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 140 kHz)	C_{ib}	-	9.0	pF
Small-Signal Current Gain ($I_C = 10$ mAdc, $V_{CE} = 1.0$ Vdc, f = 1.0 kHz)	h_{fe}	20	-	-
Real Part of Input Impedance ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc, f = 300 MHz)	$Re(h_{ie})$	-	50	Ohms
Turn-On Time (Figure 1) ($V_{CC} = 3.0$ Vdc, $V_{EB(off)} = 2.0$ Vdc, $I_C \approx 10$ mAdc, $I_{B1} \approx 3.0$ mAdc)	t_{on}	-	50	ns
Turn-Off Time (Figure 1) ($V_{CC} = 3.0$ Vdc, $I_C \approx 10$ mAdc, $I_{B1} \approx 3.0$ mAdc, $I_{B2} \approx 1.0$ mAdc)	t_{off}	-	90	ns
Storage Time (Figure 2) ($I_C \approx 10$ mAdc, $I_{B1} \approx 10$ mAdc, $I_{B2} \approx 10$ mAdc)	t_s	-	40	ns

(1) Pulse Test: Pulse width ≦ 300 µs, duty cycle ≦ 1%

FIGURE 2 — STORAGE TIME TEST CIRCUIT


V_{in}
"A"
500
890
V_{out}
0.1
500
0.0025
0.0025
91
$Z_s = 50\ \Omega$
68
10
10
+
+
−
−
$V_{BB} = 11$ Vdc
$V_{CC} = 10$ Vdc
TO OSCILLOSCOPE
$Z_{in} \geqq 100\ k\Omega$
$t_r \leqq 5.0$ ns
Capacitor values in µF
Resistor values in ohms
0
−10 Vdc
V_{in}
V_{in} rise time < 5.0 ns
+6.0 Vdc
10%
0
PULSE AT POINT "A"
−4.0 Vdc
t_s
V_{out}
10%

2N3427, 2N3428 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated
from case

PNP germanium transistors for audio amplifier and medium-speed switching applications.

MAXIMUM RATINGS

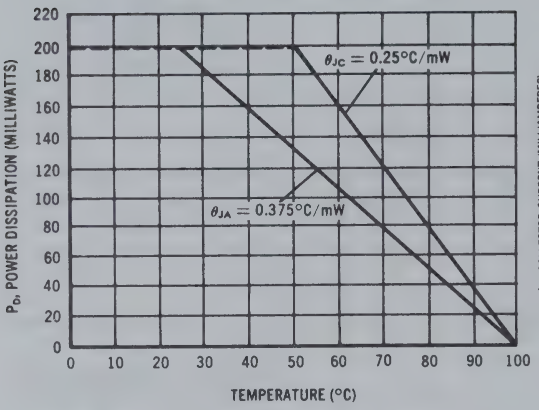
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CER}	30	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current (Continuous)	I_C	500*	mAdc
Base Current (Continuous)	I_B	50*	mAdc
Storage and Operating Temperature Range	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation, Ambient Derate Above 25°C	P_D	200 2.67	mW mW/°C

*Limited by power dissipation

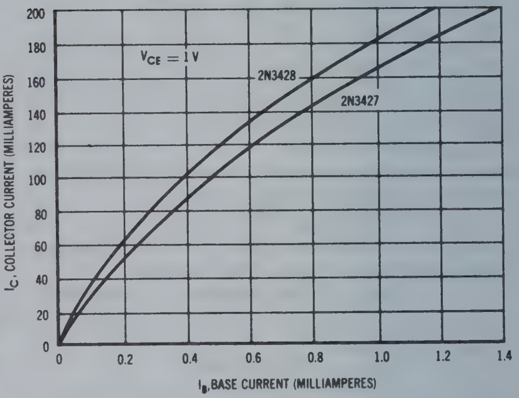
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current	I_{CBO}				μAdc
(V_{CB} = 1.5 Vdc, I_E = 0)		–	3.0	5.0	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +71°C)		–	–	100	
(V_{CB} = 30 Vdc, I_E = 0)		–	–	10	
(V_{CB} = 45 Vdc, I_E = 0)		–	–	50	
Emitter-Base Cutoff Current (V_{EB} = 30 Vdc, I_C = 0)	I_{EBO}	–	3.0	10	μAdc
Collector-Emitter Leakage Current (V_{CE} = 30 Vdc, R_{BE} = 10K ohms)	I_{CER}	–	–	600	μAdc
Collector-Emitter Punch-Thru Voltage (V_{fl} = 1.0 Vdc, VTVM impedance ≥ 1 megohm)	V_{pt}	30	–	–	Vdc
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	–	10	20	pF
Noise Figure (V_{CE} = 4.5 Vdc, I_E = 0.5 mAdc, R_s = 1 K ohms, f = 1 kHz, Δf = 1 Hz)	NF	–	5.0	10	dB
Small-Signal Current-Gain Cutoff Frequency	$f_{\alpha b}$				MHz
(V_{CB} = 6 Vdc, I_E = 1 mAdc) 2N3427		4.0	6.0	–	
2N3428		5.0	8.0	–	
Input Impedance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ib}	25	–	35	Ohms
Output Admittance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ob}	0.05	–	0.50	μmho
Small-Signal Current Gain	h_{fe}				–
(V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N3427		200	325	500	
2N3428		350	475	800	
Small-Signal Current Gain	$\|h_{fe}\|$				–
(V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 2 MHz) 2N3427		2.0	–	7.0	
2N3428		2.5	–	8.0	
DC Current Gain	h_{FE}				–
(I_C = 20 mAdc, V_{CE} = 1 Vdc) 2N3427		150	275	–	
2N3428		250	375	–	
(I_C = 100 mAdc, V_{CE} = 1 Vdc) 2N3427		100	210	350	
2N3428		150	260	400	
(I_C = 200 mAdc, V_{CE} = 1 Vdc) 2N3427		75	–	–	
2N3428		125	–	–	
Base-Emitter Input Voltage (V_{CE} = 1 Vdc, I_C = 100 mAdc)	V_{BE}	–	–	0.5	Vdc
Collector-Emitter Saturation Voltage	V_{CE} (sat)				Vdc
(I_C = 100 mAdc, I_B = 2 mAdc) 2N3427		–	0.155	0.200	
2N3428		–	0.150	0.190	
(I_C = 200 mAdc, I_B = 4 mAdc) 2N3427		–	0.220	0.300	
2N3428		–	0.200	0.280	

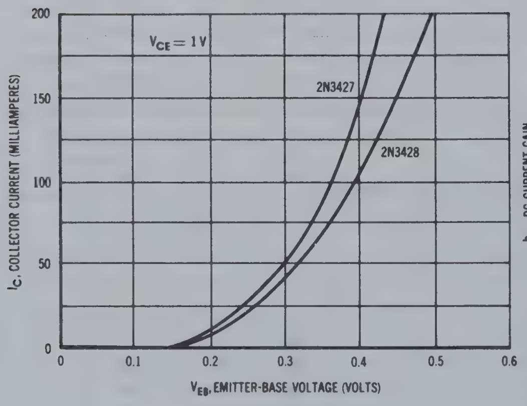
POWER-TEMPERATURE DERATING CURVE



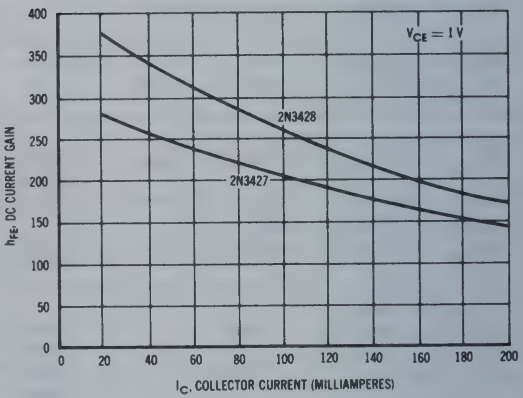
COLLECTOR CURRENT versus BASE CURRENT



OUTPUT CURRENT versus BASE DRIVE VOLTAGE



DC CURRENT GAIN versus COLLECTOR CURRENT



2N3439 (SILICON)
2N3440

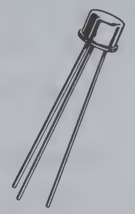
NPN SILICON HIGH VOLTAGE POWER TRANSISTORS

. . . designed for use in consumer and industrial line-operated applications. These devices are particularly suited for audio, video and differential amplifiers as well as high-voltage, low-current inverters, switching and series pass regulators.

- High DC Current Gain — h_{FE} = 40 - 160 @ I_C = 20 mAdc
- Current-Gain—Bandwidth Product — f_T = 15 MHz (Min) @ I_C = 10 mAdc
- Low Output Capacitance — C_{ob} = 10 pF (Max) @ f = 1.0 MHz

1 AMPERE
POWER TRANSISTORS
NPN SILICON

250-350 VOLTS
10 WATTS



*MAXIMUM RATINGS

Rating	Symbol	2N3439	2N3440	Unit
Collector-Emitter Voltage	V_{CEO}	350	250	Vdc
Collector-Base Voltage	V_{CB}	450	300	Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current - Continuous	I_C	1.0		Adc
Base Current	I_B	0.5		Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.7		Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	10 0.057		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

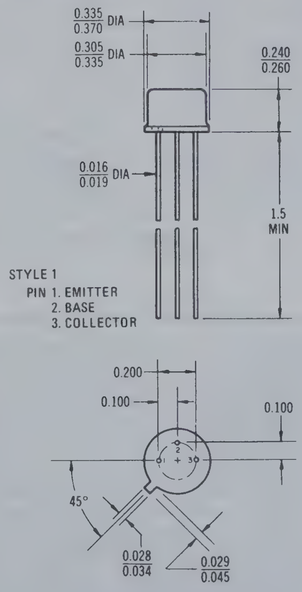
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	17.5	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	175	°C/W

ELECTRICAL CHARACTERISTICS (T_C - 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
*Collector-Emitter Sustaining Voltage (1) (I_C = 50 mAdc, I_B = 0)	2N3439 2N3440	$V_{CEO(sus)}$	350 250	– –	Vdc
Collector Cutoff Current (V_{CE} = 300 Vdc, I_B = 0) (V_{CE} = 200 Vdc, I_B = 0)	2N3439 2N3440	I_{CEO}	– –	20 50	μAdc
Collector Cutoff Current (V_{CE} = 450 Vdc, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = 300 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N3439 2N3440	I_{CEX}	- –	500 500	μAdc
*Collector Cutoff Current (V_{CB} = 360 Vdc, I_E = 0) (V_{CB} = 250 Vdc, I_E = 0)	2N3439 2N3440	I_{CBO}	– –	20 20	μAdc
*Emitter Cutoff Current (V_{BE} = 6.0 Vdc, I_C = 0)		I_{EBO}	–	20	μAdc
ON CHARACTERISTICS (1)					
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc) *(I_C = 20 mAdc, V_{CE} = 10 Vdc)	2N3439 Both Types	h_{FE}	30 40	– 160	–
*Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 4.0 mAdc)		$V_{CE(sat)}$	–	0.5	Vdc
*Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 4.0 mAdc)		$V_{BE(sat)}$	–	1.3	Vdc
***DYNAMIC CHARACTERISTICS**					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc)		f_T	15	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	–	10	pF
Input Capacitance (V_{EB} = 5.0 Vdc, I_C = 0, f = 1.0 MHz)		C_{ib}	–	75	pF
Small-signal Current Gain (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	25	–	–
Real Part of Common Emitter Small-Signal Short-Circuit Input Impedance (V_{CE} = 10 Vdc, I_C = 5.0 mAdc, f = 1.0 MHz)		$Re(h_{ie})$	–	300	Ohms

*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.



All JEDEC dimensions and notes apply

CASE 31
TO-5

2N3439, 2N3440 (continued)

FIGURE 1 – DC CURRENT GAIN

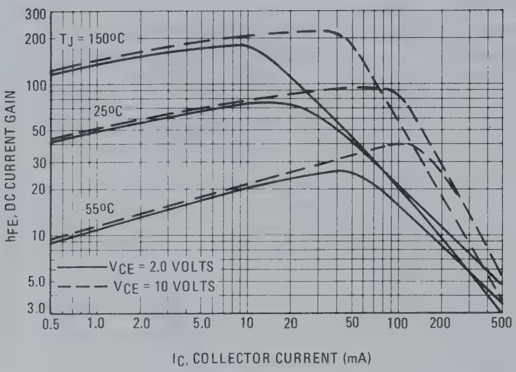


FIGURE 2 – SATURATION REGION

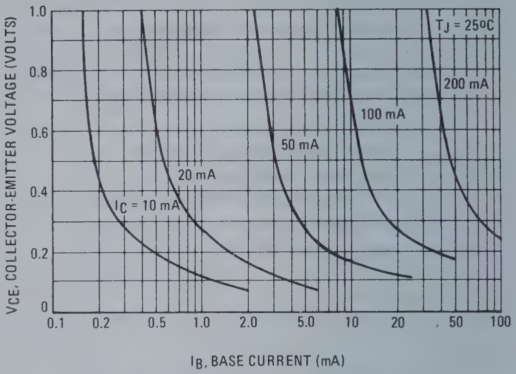


FIGURE 3 – "ON" VOLTAGES

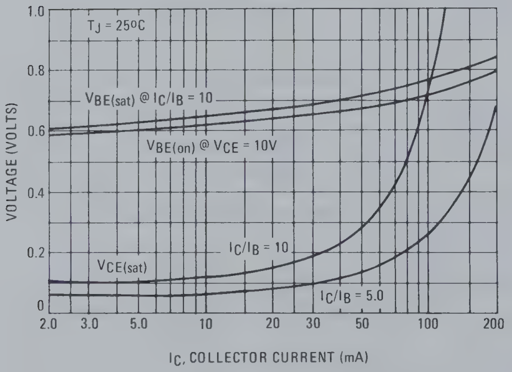


FIGURE 4 – TEMPERATURE COEFFICIENTS

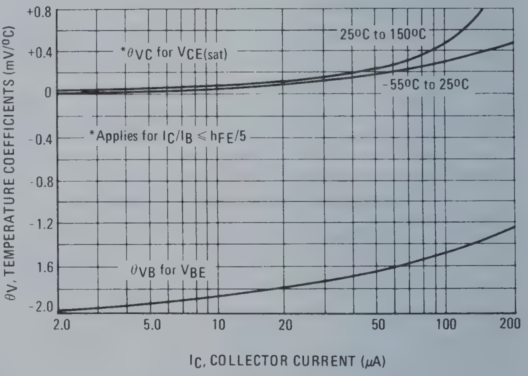


FIGURE 5 – EFFECTS OF BASE-EMITTER RESISTANCE

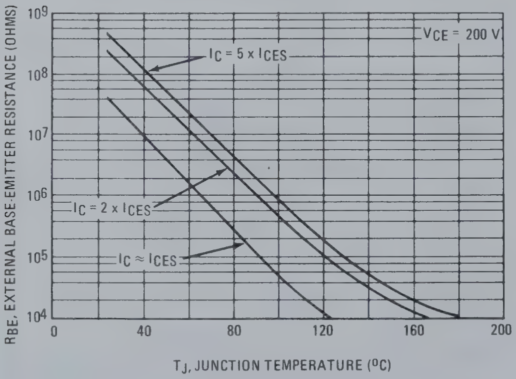


FIGURE 6 – CUT-OFF REGION

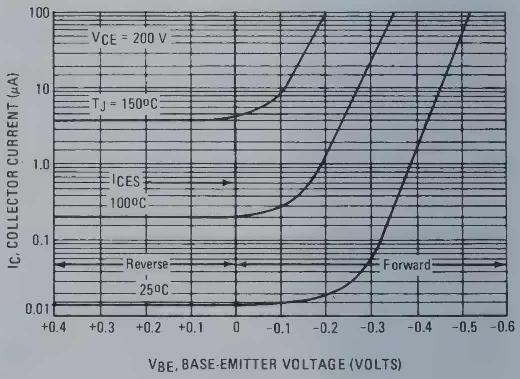


FIGURE 7 — TURN-ON TIME

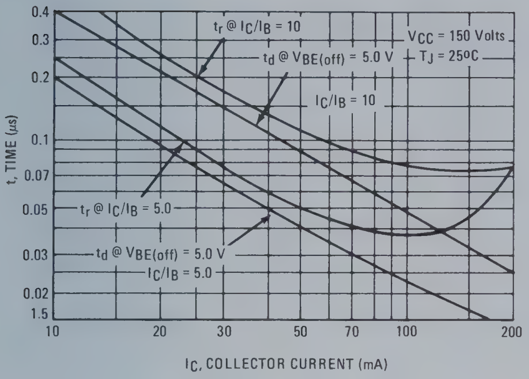


FIGURE 8 — TURN-OFF TIME

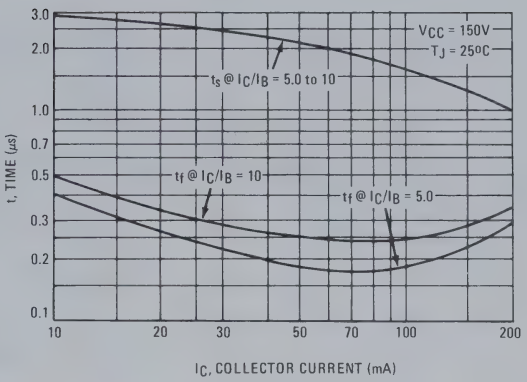
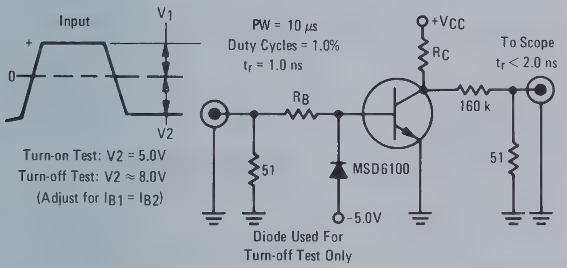


FIGURE 9 — SWITCHING TIME EQUIVALENT TEST CIRCUIT



Input
V_1
+
0
V_2
Turn-on Test: V2 = 5.0V
Turn-off Test: V2 ≈ 8.0V
(Adjust for $I_{B1} = I_{B2}$)
PW = 10 μs
Duty Cycles = 1.0%
t_r = 1.0 ns
$+V_{CC}$
R_C
To Scope
t_r < 2.0 ns
R_B
160 k
51
MSD6100
51
-5.0V
Diode Used For
Turn-off Test Only

Note: V_{CC} and R_C adjusted for $V_{CE(off)}$ = 150 V and I_C as desired, R_B chosen for desired I_{B1}, $V_1 \approx$ 10V.

FIGURE 10 — CURRENT-GAIN—BANDWIDTH PRODUCT

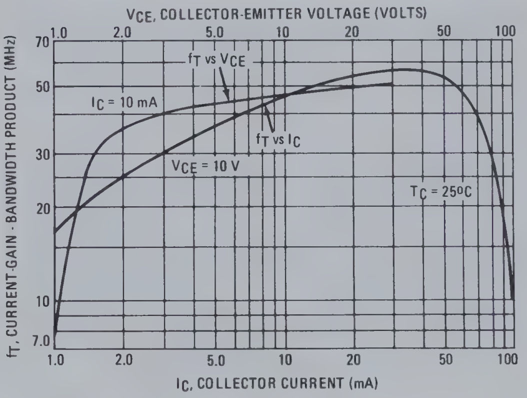


FIGURE 11 — OUTPUT ADMITTANCE

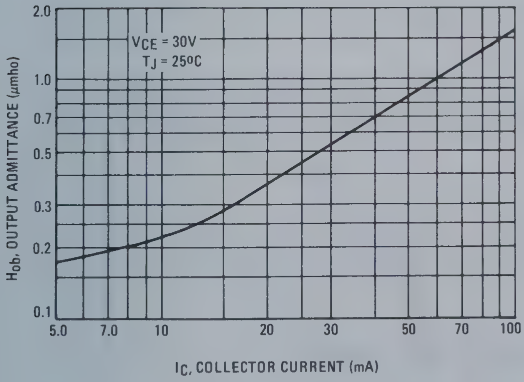


FIGURE 12 — CAPACITANCE

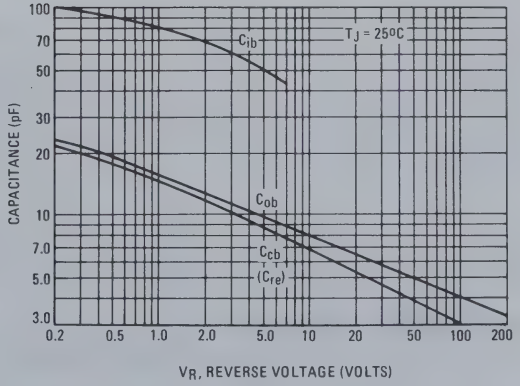


FIGURE 13 – TYPICAL THERMAL RESPONSE

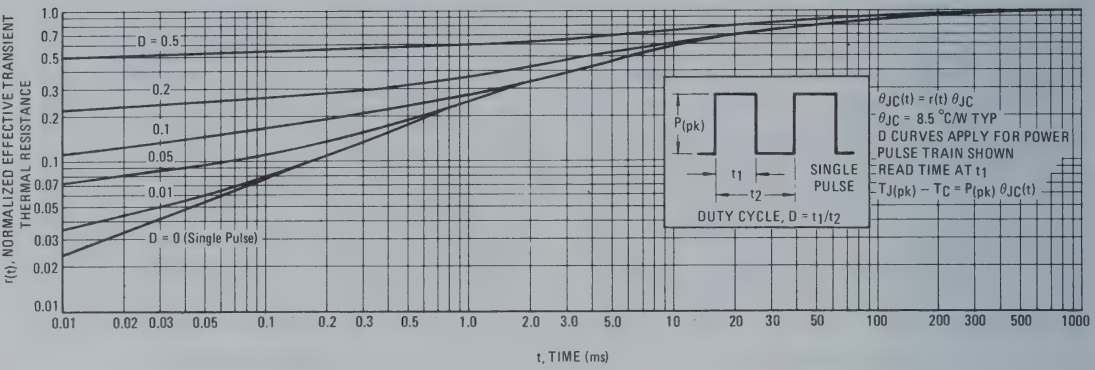


FIGURE 14 – ACTIVE-REGION SAFE OPERATING AREA

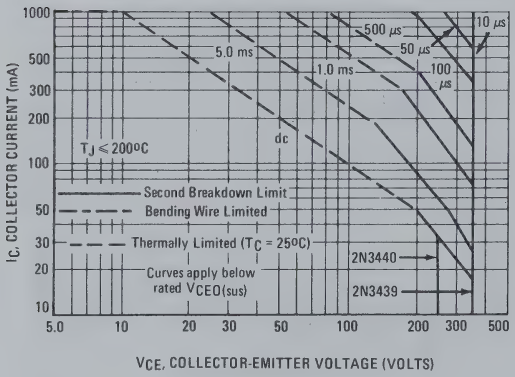
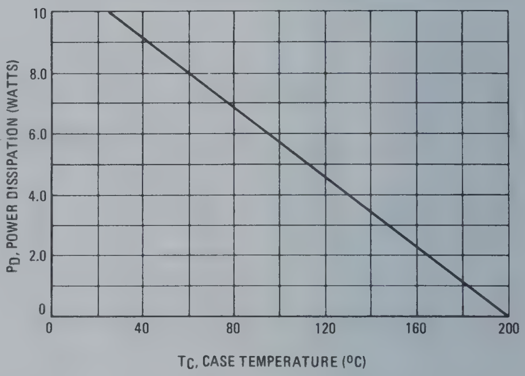


FIGURE 15 – POWER DERATING



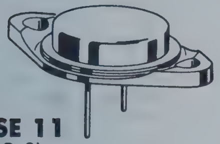
There are two limitations on the power handling ability of a transistor; average junction temperature and second breakdown. Safe operating area curves indicate $I_C \cdot V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 14 is based on $T_{J(pk)} = 200^oC$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} = 200^oC$. $T_{J(pk)}$ may be calculated from the data in Figure 13. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415)

2N3444 (SILICON)

For Specifications, See 2N3252 Data.

2N3445 thru 2N3448 (SILICON)



CASE 11
(TO-3)
Collector connected to case

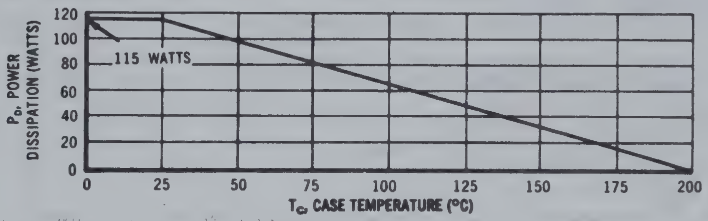
NPN silicon power transistors for switching and amplifier applications requiring fast response, wide band and good Beta linearity.

MAXIMUM RATINGS

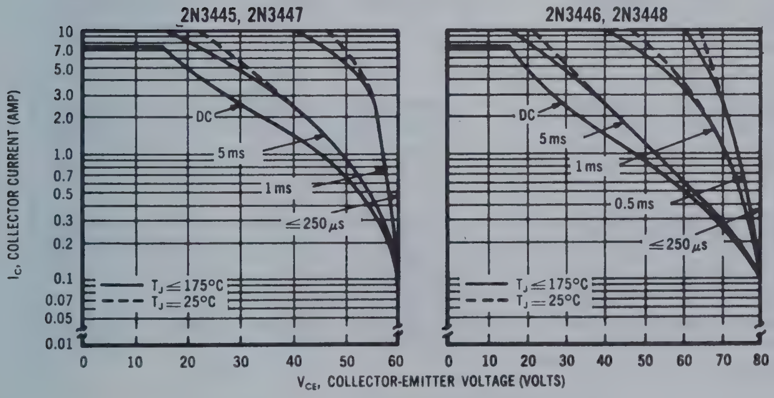
Rating	Symbol	2N3445 2N3447	2N3446 2N3448	Unit
Collector-Base Voltage	V_{CB}	80	100	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	6.0	10	Volts
Collector Current	I_C	7.5		Amp
Base Current	I_B	4.0		Amp
Power Dissipation	P_D	115		Watts
Junction Operating Temperature Range	T_J	-65 to + 200		°C

POWER-TEMPERATURE DERATING CURVE

These transistors are also subject to safe area curves. Both limits are applicable and must be observed.



SAFE OPERATING AREAS


2N3445, 2N3447

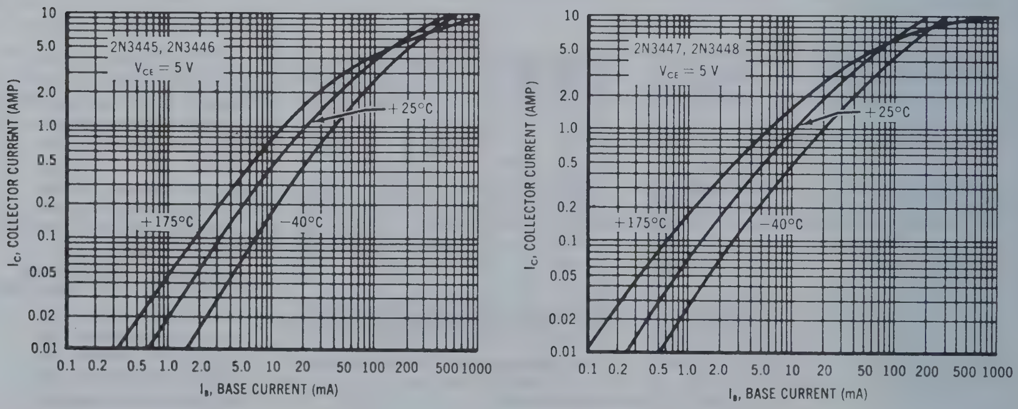
2N3446, 2N3448

The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

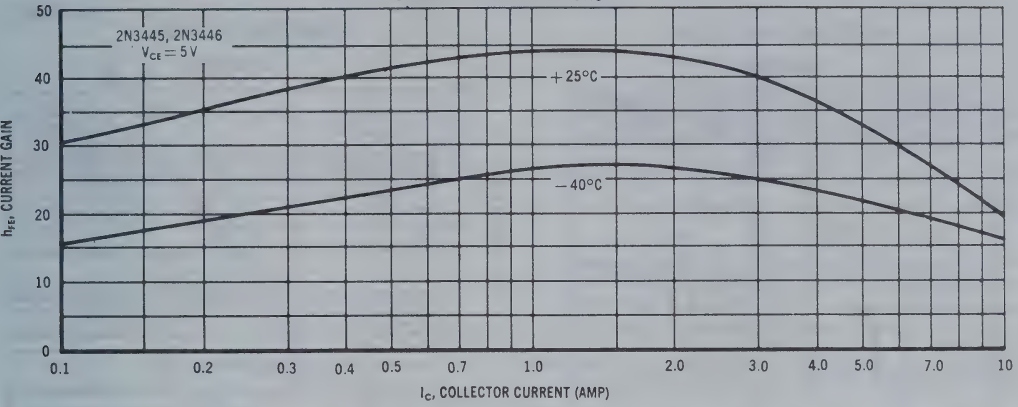
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

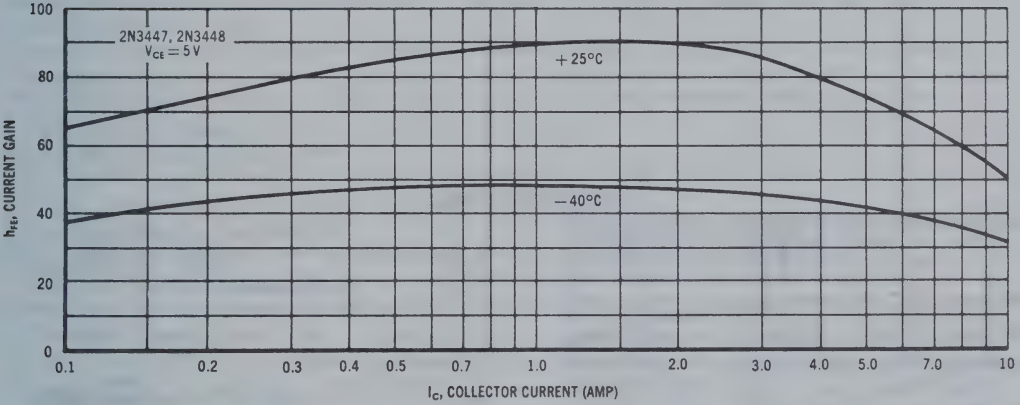
Characteristic		Symbol	Min	Typ	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}				mAdc
(V_{EB} = 6 Vdc)	2N3445, 2N3447		—	—	0.25	
(V_{EB} = 10 Vdc)	2N3446, 2N3448		—	—	0.25	
Collector-Emitter Cutoff Current		I_{CEX}				mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc)	2N3445, 2N3447		—	—	0.1	
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3445, 2N3447		—	—	1.0	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc)	2N3446, 2N3448		—	—	0.1	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3446, 2N3448		—	—	1.0	
Collector-Emitter Cutoff Current		I_{CEO}				mAdc
(V_{CE} = 40 Vdc, I_B = 0)	2N3445, 2N3447		—	—	1.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N3446, 2N3448		—	—	1.0	
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 1 mAdc, I_E = 0)	2N3445, 2N3447		80	—	—	
	2N3446, 2N3448		100	—	—	
Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$				Vdc
(I_C = 100 mAdc, I_B = 0)	2N3445, 2N3447		60	—	—	
	2N3446, 2N3448		80	—	—	
DC Current Gain		h_{FE}				—
(I_C = 0.5 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		20	45	—	
	2N3447, 2N3448		40	85	—	
(I_C = 3 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		20	40	60	
(I_C = 5 Adc, V_{CE} = 5 Vdc)	2N3447, 2N3448		40	75	120	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3445, 2N3446		—	0.6	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3447, 2N3448		—	0.8	1.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3445, 2N3446		—	1.0	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3447, 2N3448		—	1.0	1.5	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 3 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		—	1.0	1.5	
(I_C = 5 Adc, V_{CE} = 5 Vdc)	2N3447, 2N3448		—	1.0	1.4	
Small Signal Current Gain		h_{fe}				—
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 kHz)	2N3445, 2N3446		20	—	100	
	2N3447, 2N3448		40	—	200	
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 10 MHz)			1.0	1.6	—	
Common Base Output Capacitance		C_{ob}				pF
(V_{CB} = 10 Vdc, f = 0.1 MHz)			—	260	400	
Switching Times						µs
(V_{CC} ≈ 25 Vdc, R_L = 5 ohms, I_C = 5 A, I_{B1} = I_{B2} = 0.5 A)						
Delay Time plus Rise Time		$t_d + t_r$	—	0.15	0.35	
Storage Time		t_s	—	0.9	2.0	
Fall Time		t_f	—	0.15	0.35	

COLLECTOR CURRENT versus BASE CURRENT

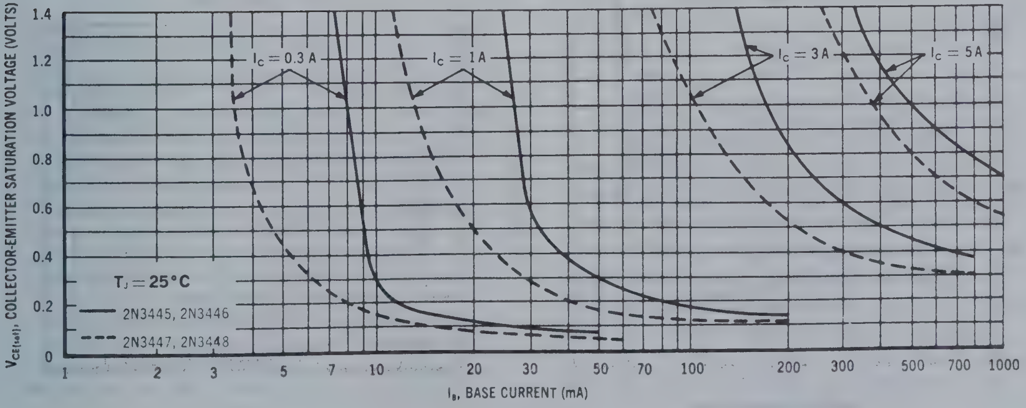


CURRENT GAIN VARIATIONS

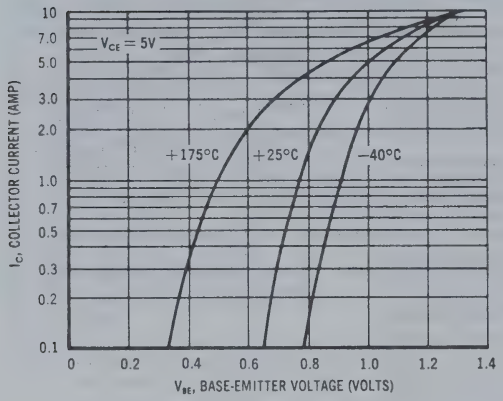




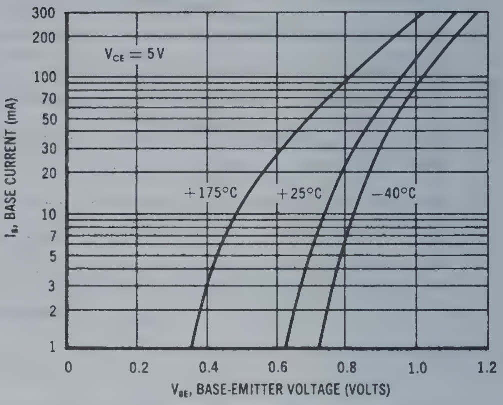
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



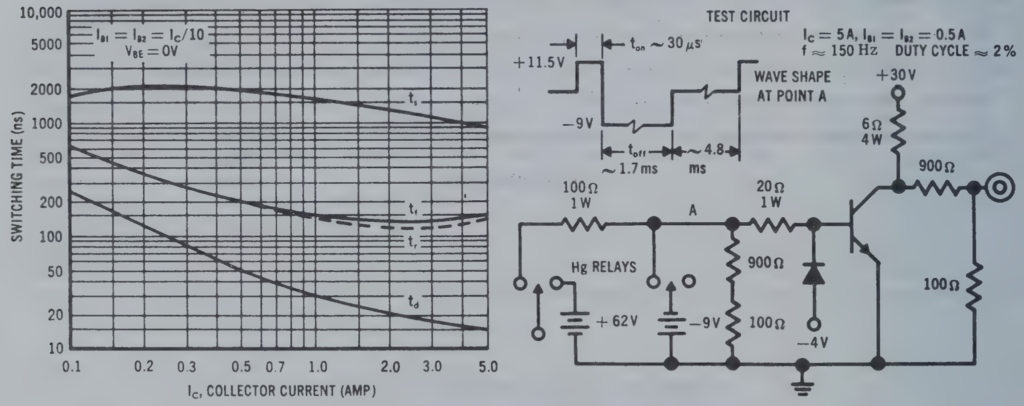
COLLECTOR CURRENT-VOLTAGE VARIATIONS



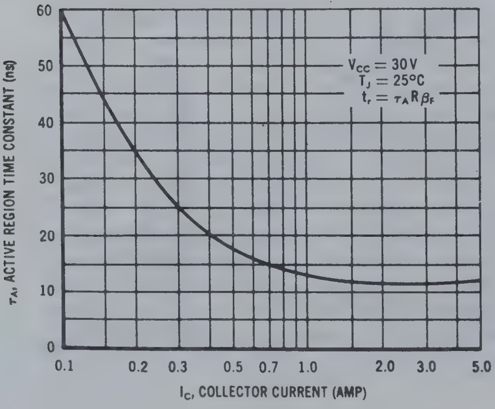
BASE CURRENT-VOLTAGE VARIATIONS



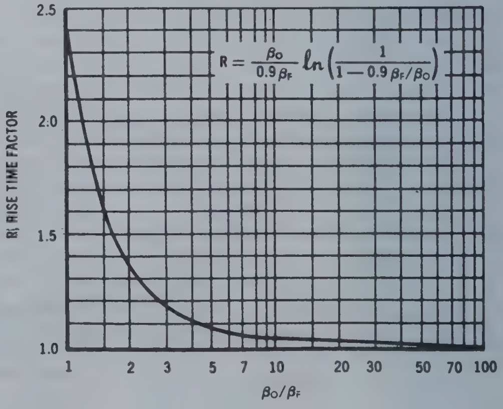
TYPICAL SWITCHING TIMES



ACTIVE REGION TIME CONSTANT

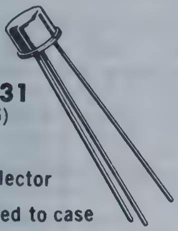


RISE TIME FACTOR



2N3467, 2N3468 (SILICON)

2N3467 JAN AVAILABLE
2N3468 JAN AVAILABLE


CASE 31
(TO-5)

Collector
connected to case

PNP silicon annular transistors for high-speed switching and driver applications.

MAXIMUM RATINGS

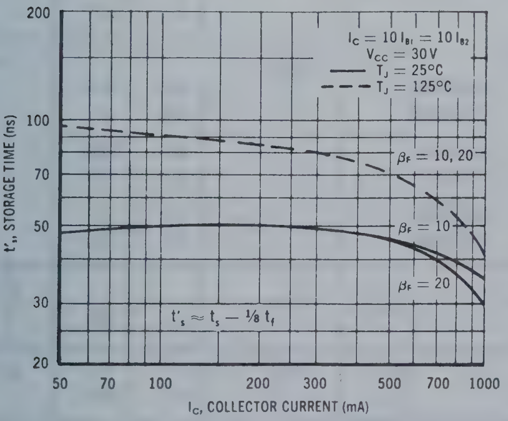
Rating	Symbol	2N3467	2N3468	Unit
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ $T_A = 25^{o}C$ Derating Factor Above $25^{o}C$	P_D	1.0 5.71		Watt $mW/^{o}C$
Total Device Dissipation @ $T_C = 25^{o}C$ Derating Factor Above $25^{o}C$	P_D	5.0 28.6		Watts $mW/^{o}C$
Junction Temperature, Operating	T_J	+200		^{o}C
Storage Temperature Range	T_{stg}	-65 to +200		^{o}C

THERMAL RESISTANCE

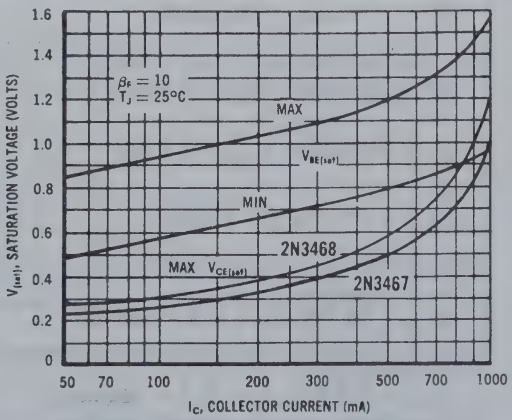
θ_{JA} (air) = 0.175°C/mW

θ_{JC} (case) = 35°C/W

STORAGE TIME VARIATION WITH TEMPERATURE



LIMITS OF SATURATION VOLTAGE



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

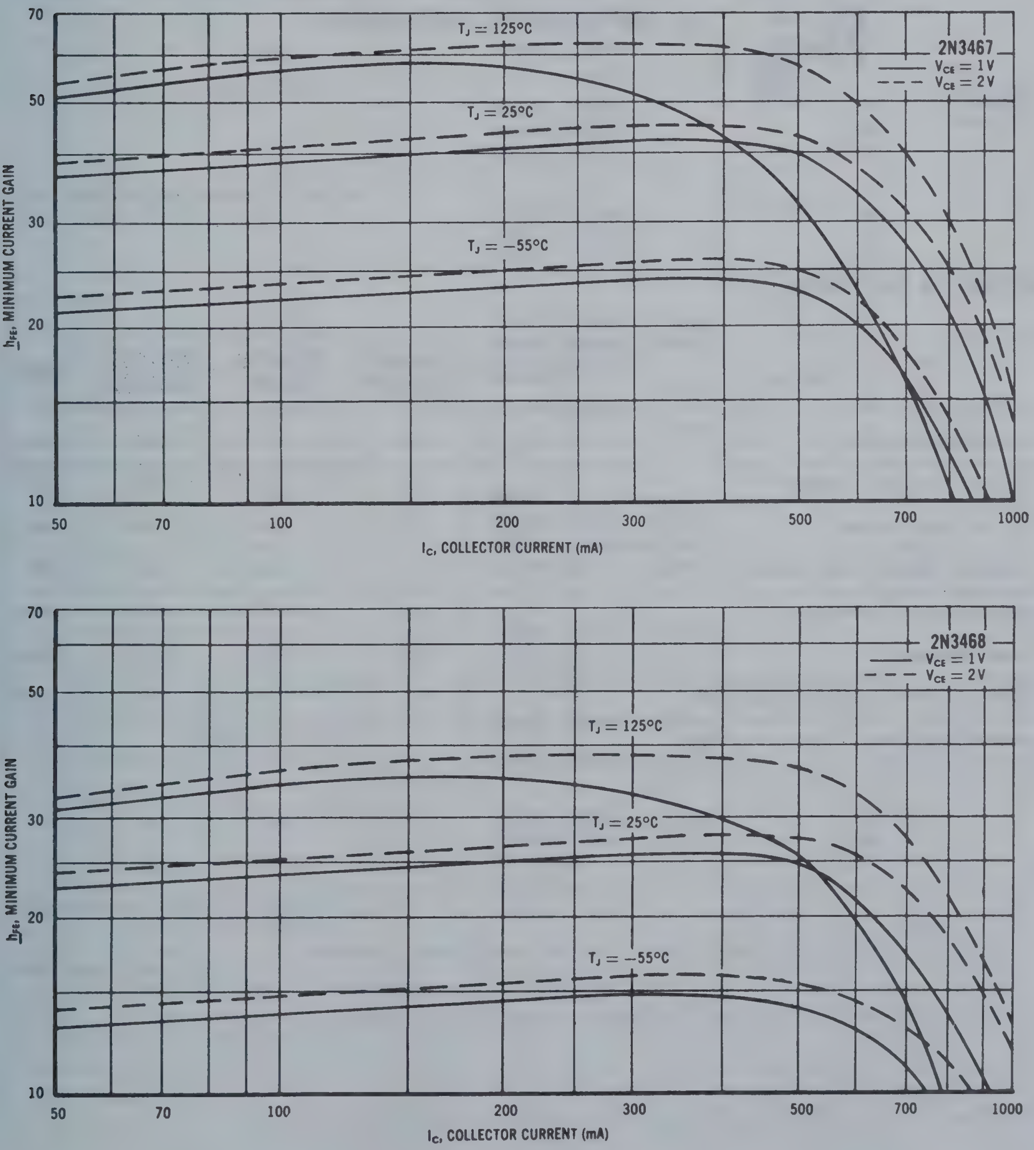
Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)			—	0.10	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 100°C)			—	15	
Collector Cutoff Current		I_{CEX}			nAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			—	100	
Base Cutoff Current		I_{BL}			nAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			—	120	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3467		40	—	
	2N3468		50	—	
Collector-Emitter Breakdown Voltage (1)		BV_{CEO}			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3467		40	—	
	2N3468		50	—	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)			5.0	—	
Collector Saturation Voltage (1)		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N3467		—	0.3	
	2N3468		—	0.35	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3467		—	0.5	
	2N3468		—	0.6	
(I_C = 1 Adc, I_B = 100 mAdc)	2N3467		—	1.0	
	2N3468		—	1.2	
Base-Emitter Saturation Voltage (1)		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)			0.8	1.2	
(I_C = 1 Adc, I_B = 100 mAdc)			—	1.6	
DC Forward Current Transfer Ratio (1)		h_{FE}			—
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N3467		40	—	
	2N3468		25	—	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	2N3467		40	120	
	2N3468		25	75	
(I_C = 1 Adc, V_{CE} = 5 Vdc)	2N3467		40	—	
	2N3468		25	—	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)			—	25	
Input Capacitance		C_{ib}			pF
(V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)			—	100	
Current-Gain - Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3467		175	—	
	2N3468		150	—	

(1) Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
Delay Time	(I_C = 500 mA, I_{B1} = 50 mA, V_{BE} = 2 V, V_{CC} = 30 V)	t_d	—	10	ns
Rise Time		t_r	—	30	ns
Storage Time	(I_C = 500 mA, I_{B1} = I_{B2} = 50 mA, V_{CC} = 30 V)	t_s	—	60	ns
Fall Time		t_f	—	30	ns
Total Control Charge (I_C = 500 mA, I_B = 50 mA, V_{CC} = 30 V)		Q_T	—	6.0	nC

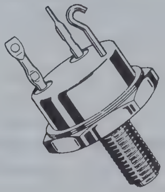
MINIMUM CURRENT GAIN CHARACTERISTICS



2N3485, A (SILICON)
2N3486, A

For Specifications, See 2N2904 Data.

2N3487 thru 2N 3492 (SILICON)



CASE 9
(TO-61)

NPN silicon power transistors designed for switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3487 2N3490	2N3488 2N3491	2N3489 2N3492	Unit
Collector-Base Voltage	V_{CB}	80	100	120	Vdc
Collector-Emitter Voltage	V_{CEO}	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	10	10	10	Vdc
Collector Current (Continuous)	I_C	7.5	7.5	7.5	Adc
Base Current (Continuous)	I_B	4.0	4.0	4.0	Adc
Power Dissipation	P_D	117	117	117	Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5	1.5	1.5	$^{o}C/W$
Junction Operating Temperature Range	T_J	$-65^{o}C$ to $+200^{o}C$			^{o}C

2N3487 thru 2N3492 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Emitter-Base Cutoff Current (V_{EB} = 10 Vdc)	I_{EBO}	-	0.10	mAdc
Collector-Emitter Cutoff Current	I_{CEX}			μAdc
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc) 2N3487, 2N3490		-	25	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc) 2N3488, 2N3491		-	25	
(V_{CE} = 100 Vdc, V_{BE} = -1 Vdc) 2N3489, 2N3492		-	25	
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc, $T_C = 150^\circ C$) 2N3487, 2N3490		-	250	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc, $T_C = 150^\circ C$) 2N3488, 2N3491		-	250	
(V_{CE} = 100 Vdc, V_{BE} = -1 Vdc, $T_C = 150^\circ C$) 2N3489, 2N3492		-	250	
Collector-Emitter Cutoff Current	I_{CEO}			μAdc
(V_{CE} = 40 Vdc, I_B = 0) 2N3487, 2N3490		-	250	
(V_{CE} = 60 Vdc, I_B = 0) 2N3488, 2N3491		-	250	
(V_{CE} = 80 Vdc, I_B = 0) 2N3489, 2N3492		-	250	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 100 μAdc, I_E = 0) 2N3487, 2N3490		80	-	
2N3488, 2N3491		100	-	
2N3489, 2N3492		120	-	
Collector-Emitter Sustaining Voltage	$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0) 2N3487, 2N3490		60	-	
2N3488, 2N3491		80	-	
2N3489, 2N3490		100	-	
DC Current Gain	h_{FE}			-
(I_C = 0.5 Adc, V_{CE} = 5 Vdc) 2N3487, 2N3488, 2N3489		20	-	
2N3490, 2N3491, 2N3492		40	-	
(I_C = 3.0 Adc, V_{CE} = 5 Vdc) 2N3487, 2N3488		20	60	
2N3489		15	45	
(I_C = 5.0 Adc, V_{CE} = 5 Vdc) 2N3490, 2N3491		40	120	
2N3492		30	90	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 1 Adc, I_B = 0.1 Adc)		-	0.3	
(I_C = 3 Adc, I_B = 0.3 Adc) 2N3487, 2N3488, 2N3489		-	1.2	
2N3490, 2N3491, 2N3492		-	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc) 2N3490, 2N3491, 2N3492		-	1.5	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 3 Adc, I_B = 0.3 Adc) 2N3487, 2N3488, 2N3489		-	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc) 2N3490, 2N3491, 2N3492		-	1.5	
Base-Emitter Voltage	V_{BE}			Vdc
(I_C = 3 Adc, V_{CE} = 5 Vdc) 2N3487, 2N3488, 2N3489		-	1.5	
(I_C = 5 Adc, V_{CE} = 5 Vdc) 2N3490, 2N3491, 2N3492		-	1.4	
Small Signal Current Gain	h_{fe}			-
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 kHz) 2N3487, 2N3488, 2N3489		20	100	
2N3490, 2N3491, 2N3492		40	200	
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 10 MHz) All Types		1.0	-	
Common Base Output Capacitance (V_{CB} = 10 Vdc, f = 0.1 MHz)	C_{ob}	-	550	pF
Switching Times ($V_{CC} \approx 25$ Vdc, $R_L = 5\Omega$, I_C = 5 Adc, $I_{B_1} = -I_{B_2}$ = 0.5 Adc)		-	-	μs
Delay Time plus Rise Time	$t_d + t_r$	-	0.35	μs
Storage Time	t_s	-	2.0	
Fall Time	t_f	-	0.35	

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE

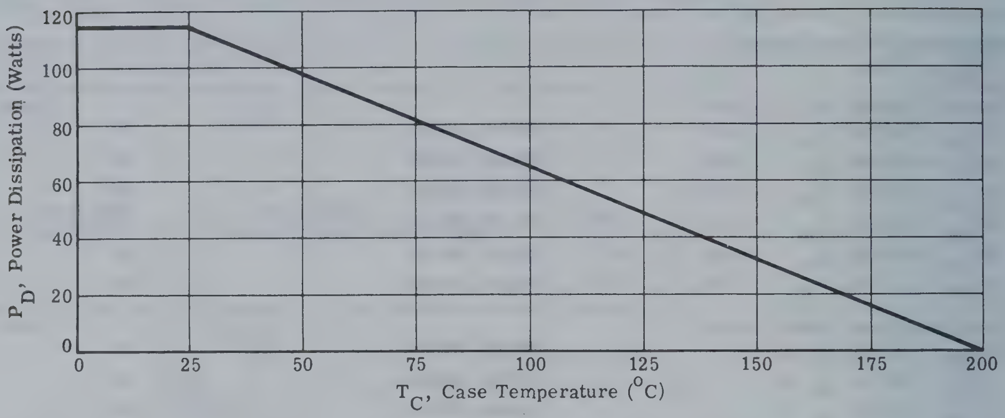
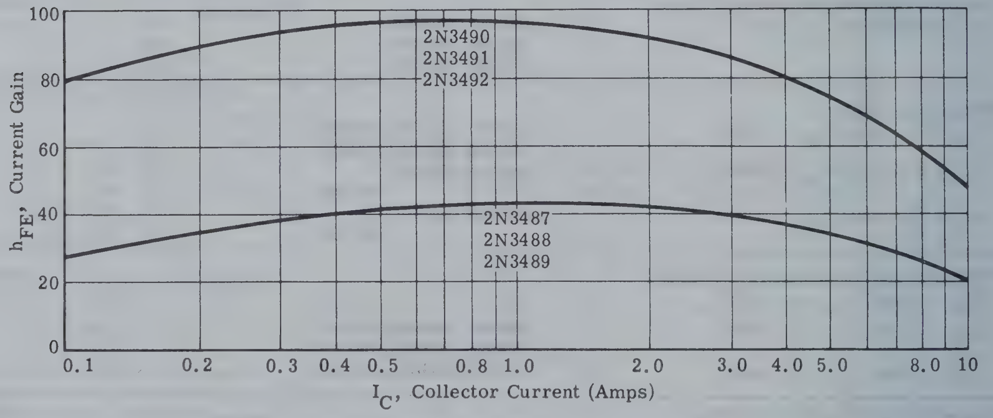


FIGURE 2 — DC CURRENT GAIN versus COLLECTOR CURRENT



ACTIVE - REGION SAFE OPERATING AREAS

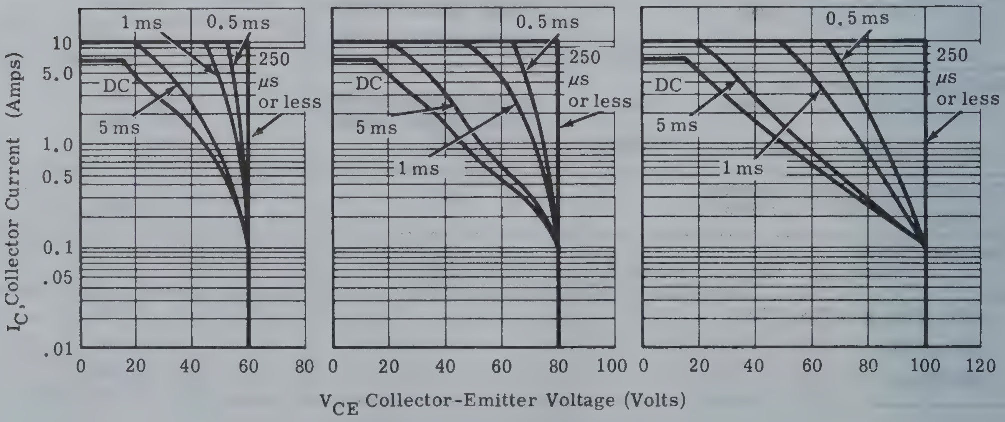


FIGURE 3 — 2N3487, 2N3490

FIGURE 4 — 2N3489, 2N3492

FIGURE 5 — 2N3488, 2N3491

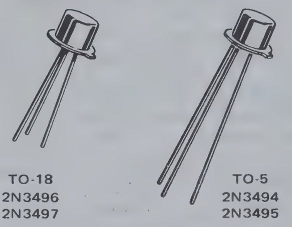
2N3494 (SILICON)
thru
2N3497

PNP SILICON ANNULAR STAR TRANSISTORS

. . . designed for high-voltage switching circuits and DC to VHF amplifier applications.

- High Collector-Emitter Breakdown Voltage – BV_{CEO} = 120 Vdc (Min) @ I_C = 10 mAdc (2N3495,97)
- Low Collector-Emitter Saturation Voltage – $V_{CE(sat)}$ = 0.3 Vdc (Max) @ I_C = 10 mAdc (2N3494,96)
- High Current-Gain–Bandwidth Product – f_T = 200 MHz (Min) @ I_C = 20 mAdc (2N3494,96)

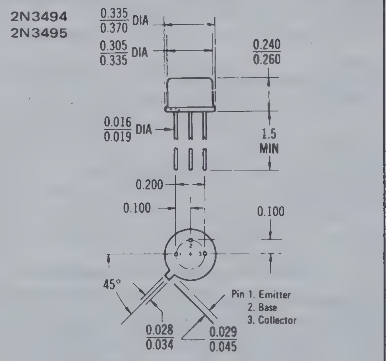
PNP SILICON HIGH-VOLTAGE TRANSISTORS


TO-18
2N3496
2N3497
TO-5
2N3494
2N3495

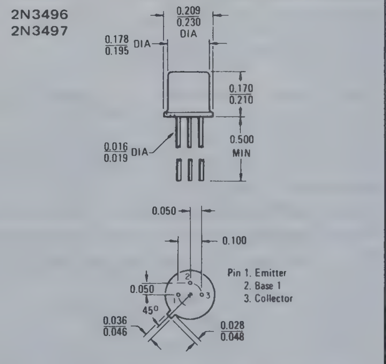
*MAXIMUM RATINGS

Rating	Symbol	2N3494 2N3496	2N3495 2N3497	Unit
Collector-Emitter Voltage	V_{CEO}	80	120	Vdc
Collector-Base Voltage	V_{CB}	80	120	Vdc
Emitter-Base Voltage	V_{EB}	4.5		Vdc
Collector Current – Continuous	I_C	100		mAdc
		2N3494 2N3495	2N3496 2N3497	
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	600 3.43	400 2.28	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$** Derate above 25^oC	P_D	2.0 11.4	1.2 6.85	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*Indicates JEDEC Registered Data.
**Motorola guarantees this data in addition to JEDEC Registered Data.


2N3494
2N3495
0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
0.016
0.019
DIA
1.5
MIN
0.200
0.100
0.100
45°
Pin 1. Emitter
2. Base
3. Collector
0.028
0.034
0.029
0.045

TO-5 PACKAGE CASE 31 (1)


2N3496
2N3497
0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.016
0.019
DIA
0.500
MIN
0.050
0.100
0.050
45°
Pin 1. Emitter
2. Base 1
3. Collector
0.036
0.046
0.028
0.048

TO-18 PACKAGE CASE 22 (1)

2N3494 thru 2N3497 (continued)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage(1)		BV_{CEO}			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3494, 2N3496		80	–	
	2N3495, 2N3497		120	–	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3494, 2N3496		80	–	
	2N3495, 2N3497		120	–	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	–	Vdc
Collector Cutoff Current		I_{CBO}			nAdc
(V_{CB} = 50 Vdc, I_E = 0)	2N3494, 2N3496		–	100	
(V_{CB} = 90 Vdc, I_E = 0)	2N3495, 2N3497		–	100	
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	–	25	nAdc
ON CHARACTERISTICS					
DC Current Gain(1)		h_{FE}			–
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	All Types		35	–	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	All Types		40	–	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	All Types		40	–	
(I_C = 50 mAdc, V_{CE} = 10 Vdc)	All Types		40	–	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)	2N3494, 2N3496		35	–	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)	2N3494, 2N3496		–	0.3	
	2N3495, 2N3497		–	0.35	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{BE(sat)}$	0.6	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product(2)		f_T			MHz
(I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3494, 2N3496		200	–	
	2N3495, 2N3497		150	–	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3494, 2N3496		–	7.0	
	2N3495, 2N3497		–	6.0	
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	–	30	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{ie}	0.1	1.2	k ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{re}	–	2.0	X 10^{-4}
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	40	300	–
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	–	300	μmhos
Real Part of Input Impedance (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 300 MHz)		$Re(h_{ie})$	–	30	Ohms
SWITCHING CHARACTERISTICS					
Turn-On Time (V_{CC} = 30 Vdc, I_C = 10 mAdc, I_{B1} = 10 mAdc) (See Figure 1)		t_{on}	–	300	ns
Turn-Off Time (V_{CC} = 30 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc) (See Figure 2)		t_{off}	–	1000	ns

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle = 2.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

FIGURE 1 – TURN-ON TIME TEST CIRCUIT

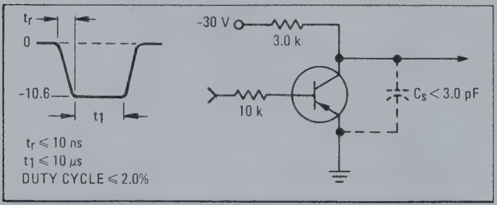
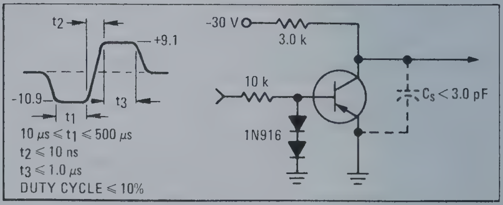
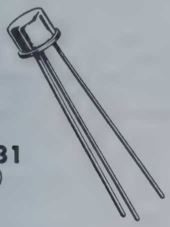


FIGURE 2 – TURN-OFF TIME TEST CIRCUIT



2N3498 thru 2N3501 (SILICON)

JAN, JTX AVAILABLE



CASE 31
(TO-5)

Collector connected to case

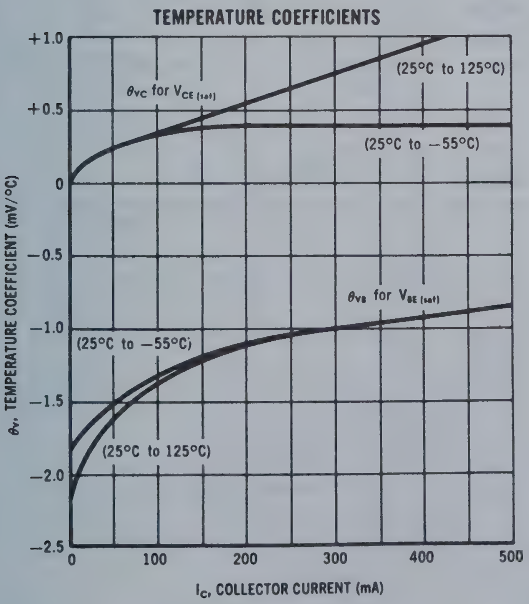
NPN silicon annular transistors for high-voltage switching and low-power amplifier applications.

MAXIMUM RATINGS

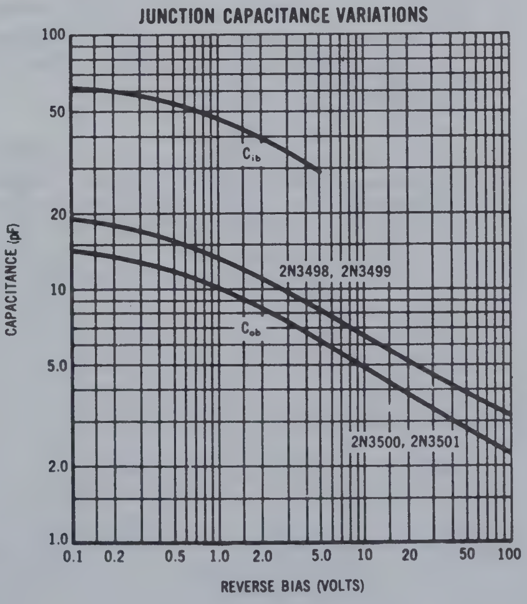
Rating	Symbol	2N3498 2N3499	2N3500 2N3501	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	Vdc
Collector-Base Voltage	V_{CB}	100	150	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	500	300	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	2N3498 2N3499	2N3500 2N3501	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35		°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.175		°C/mW



TEMPERATURE COEFFICIENTS



JUNCTION CAPACITANCE VARIATIONS

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1)	BV_{CEO}			Vdc
(I_C = 10 mAdc, I_B = 0) 2N3498, 2N3499		100	-	
2N3500, 2N3501		150	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0) 2N3498, 2N3499		100	-	
2N3500, 2N3501		150	-	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0) 2N3498, 2N3499		-	0.050	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C) 2N3498, 2N3499		-	50	
(V_{CB} = 75 Vdc, I_E = 0) 2N3500, 2N3501		-	0.050	
(V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C) 2N3500, 2N3501		-	50	
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	25	nAdc
ON CHARACTERISTICS				
DC Current Gain (1)	h_{FE}			-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3498, 2N3500		20	-	
2N3499, 2N3501		35	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N3498, 2N3500		25	-	
2N3499, 2N3501		50	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N3498, 2N3500		35	-	
2N3499, 2N3501		75	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N3498, 2N3500		40	120	
2N3499, 2N3501		100	300	
(I_C = 300 mAdc, V_{CE} = 10 Vdc) 2N3500		15	-	
2N3501		20	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc) 2N3498		15	-	
2N3499		20	-	
Collector-Emitter Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.2	
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	0.25	
(I_C = 150 mAdc, I_B = 15 mAdc) 2N3500, 2N3501		-	0.4	
(I_C = 300 mAdc, I_B = 30 mAdc) 2N3498, 2N3499		-	0.6	
Base-Emitter Saturation Voltage (1)	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.8	
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	0.9	
(I_C = 150 mAdc, I_B = 15 mAdc) 2N3500, 2N3501		-	1.2	
(I_C = 300 mAdc, I_B = 30 mAdc) 2N3498, 2N3499		-	1.4	

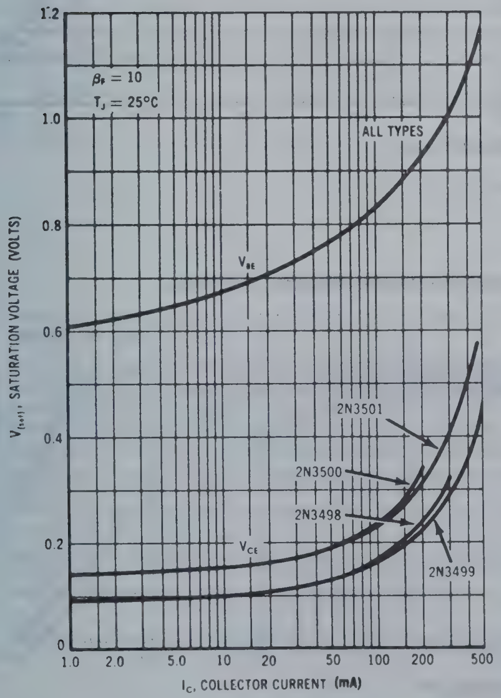
(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

ELECTRICAL CHARACTERISTICS (continued)

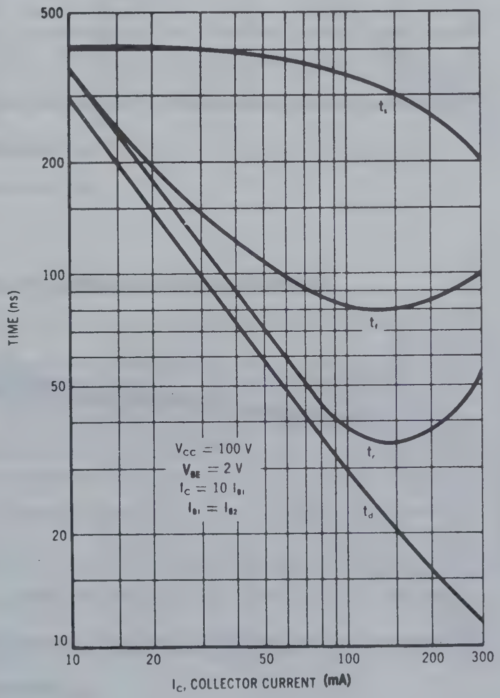
Characteristic		Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	150	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3498, 2N3499 2N3500, 2N3501	C_{ob}	- -	10 8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	80	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3498, 2N3500 2N3499, 2N3501	h_{ie}	0.2 0.25	1.0 1.25	k ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3498, 2N3500 2N3499, 2N3501	h_{re}	- -	2.5 4.0	X 10^{-4}
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3498, 2N3500 2N3499, 2N3501	h_{fe}	50 75	300 375	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3498, 2N3500 2N3499, 2N3501	h_{oe}	10 20	100 200	μmhos

SWITCHING CHARACTERISTICS			Typ	
Delay Time	(V_{CC} = 100 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc)	t_d	20	ns
Rise Time		t_r	35	ns
Storage Time	(V_{CC} = 100 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)	t_s	300	ns
Fall Time		t_f	80	ns

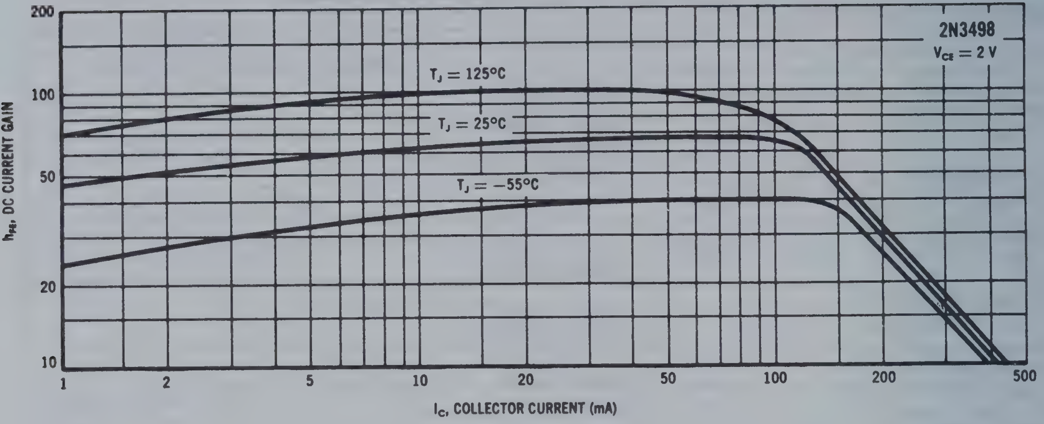
SATURATION VOLTAGES

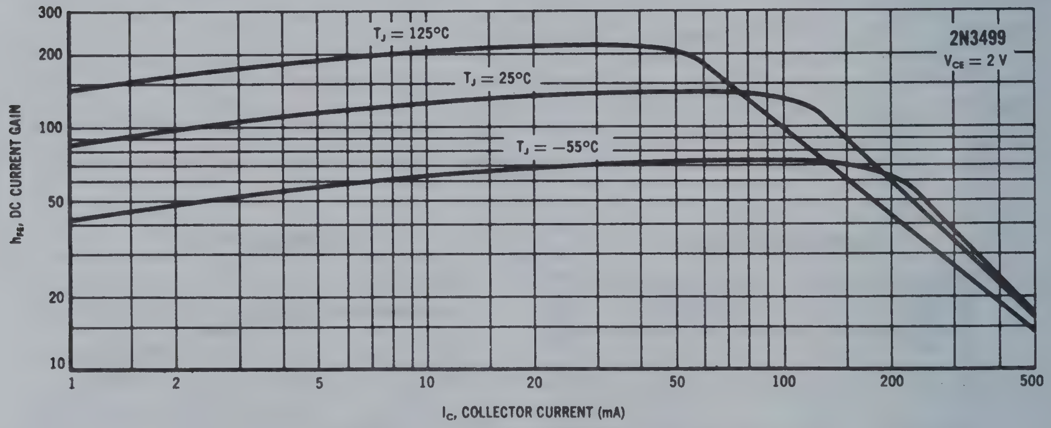


SWITCHING TIMES

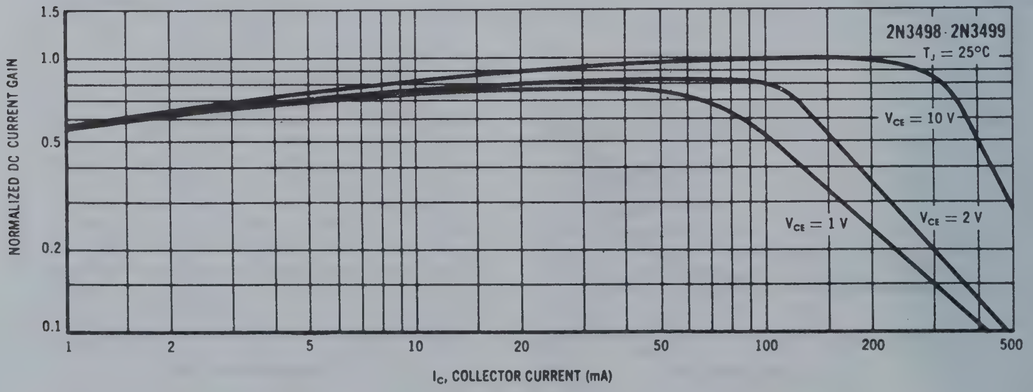


CURRENT GAIN CHARACTERISTICS vs JUNCTION TEMPERATURE

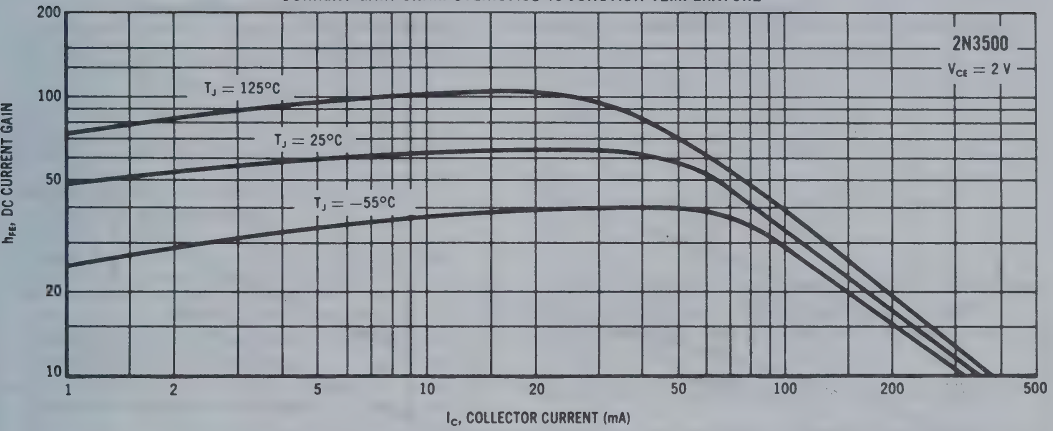


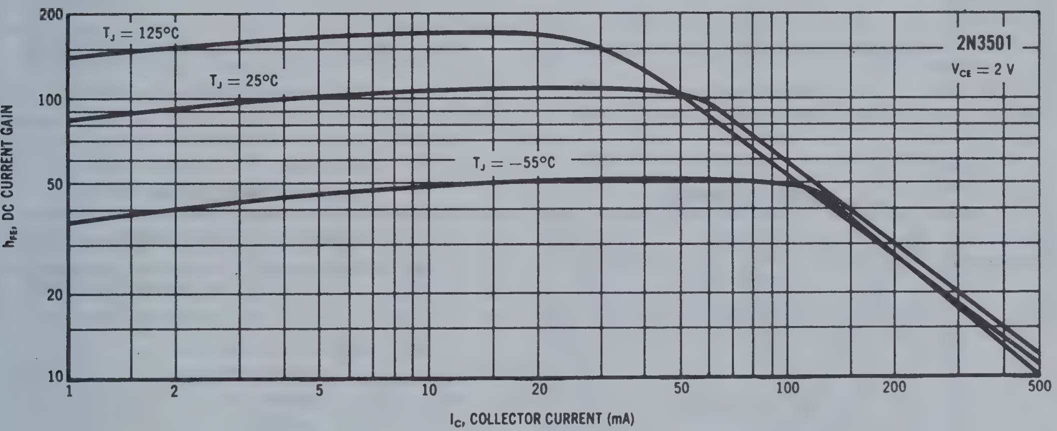


CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE

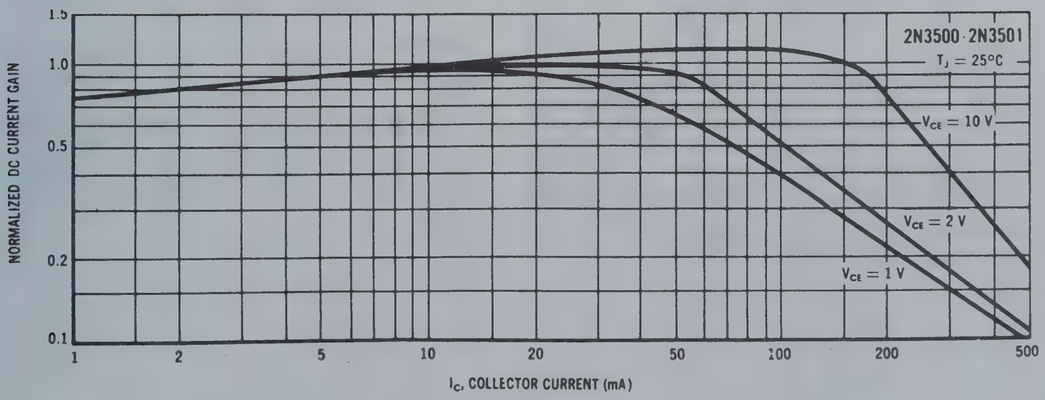


CURRENT GAIN CHARACTERISTICS vs JUNCTION TEMPERATURE



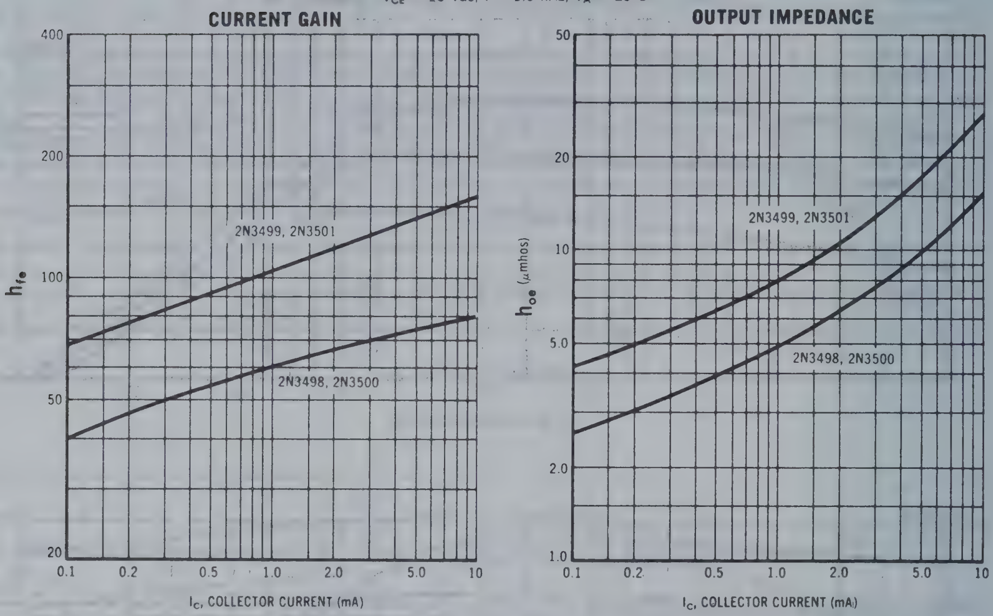


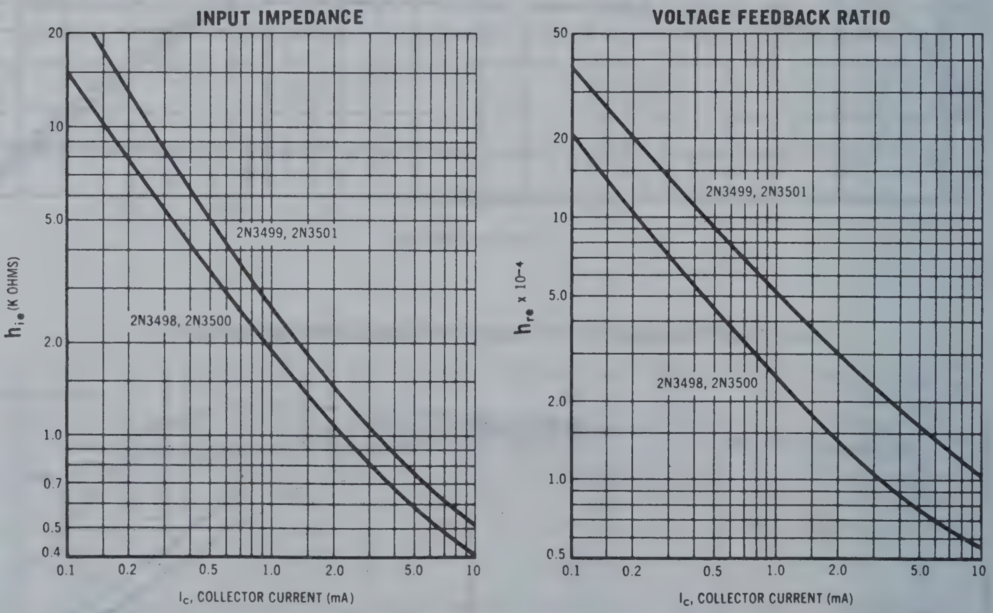
CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE



SMALL SIGNAL h PARAMETER CHARACTERISTICS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C





2N3506, 2N3507 (SILICON)

CASE 31
(TO-5)
Collector connected to case

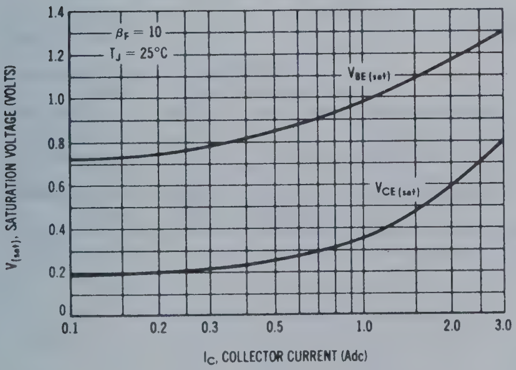
NPN silicon annular transistors for high-current, high-speed, saturated switching and core driver applications.

MAXIMUM RATINGS

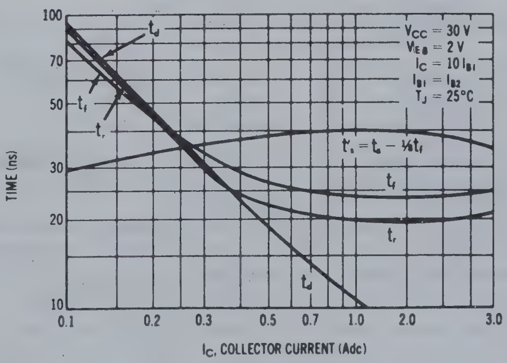
Rating	Symbol	2N3506	2N3507	Unit
Collector-Base Voltage	V_{CB}	60	80	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	3.0		Adc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	5.0 28.6		Watts mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	1.0 5.71		Watts mW/°C
Junction Operating Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

THERMAL RESISTANCE $\theta_{JA} = 0.175°C/mW$
$\theta_{JC} = 35°C/W$

SATURATION VOLTAGES



SWITCHING TIMES



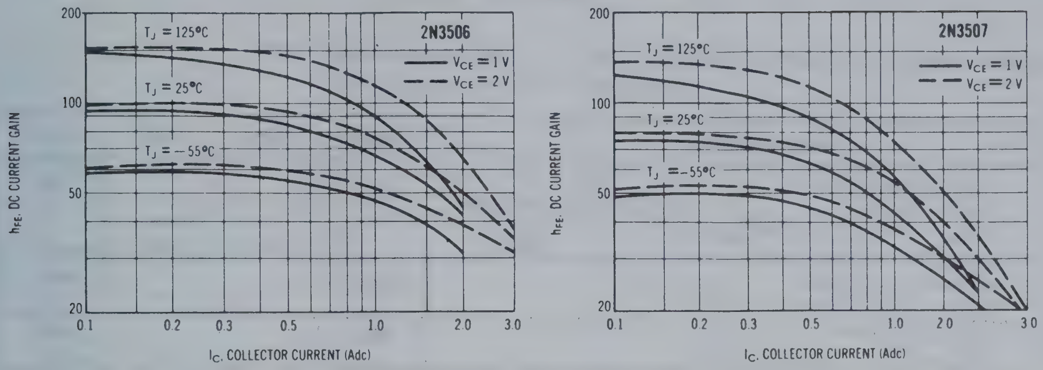
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current	I_{CEX}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3506		--	1.0	
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc, T_A = 100°C)		--	150	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3507		--	1.0	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc, T_A = 100°C)		--	150	
Base Cutoff Current	I_{BL}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3506		--	1.0	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3507		--	1.0	
Collector-Base Breakdown Voltage 2N3506 (I_C = 100 μAdc, I_E = 0) 2N3507	BV_{CBO}	60 80	-- --	Vdc
Collector-Emitter Breakdown Voltage (1) 2N3506 (I_C = 10 mAdc, pulsed, I_B = 0) 2N3507	BV_{CEO}	40 50	-- --	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	--	Vdc
Collector Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)		--	0.5	
(I_C = 1.5 Adc, I_B = 150 mAdc)		--	1.0	
(I_C = 2.5 Adc, I_B = 250 mAdc)		--	1.5	
Base-Emitter Saturation Voltage (1)	$V_{BE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)		--	1.0	
(I_C = 1.5 Adc, I_B = 150 mAdc)		0.9	1.4	
(I_C = 2.5 Adc, I_B = 250 mAdc)		--	2.0	
DC Current Gain (1)	h_{FE}			--
(I_C = 500 mAdc, V_{CE} = 1 Vdc) 2N3506		50	--	
2N3507		35	--	
(I_C = 1.5 Adc, V_{CE} = 2 Vdc) 2N3506		40	200	
2N3507		30	150	
(I_C = 2.5 Adc, V_{CE} = 3 Vdc) 2N3506		30	--	
2N3507		25	--	
(I_C = 3.0 Adc, V_{CE} = 5 Vdc) 2N3506		25	--	
2N3507		20	--	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	--	40	pF
Input Capacitance (V_{BE} = 3 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	--	300	pF
Current Gain-Bandwidth Product (I_C = 100 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)	f_T	60	--	MHz
Delay Time — I_C = 1.5 Adc, I_{B1} = 150 mAdc	t_d	--	15	ns
Rise Time — V_{CC} = 30 V, V_{EB} = 0 V	t_r	--	30	ns
Storage Time — I_C = 1.5 Adc, I_{B1} = I_{B2} = 150 mAdc	t_s	--	55	ns
Fall Time — V_{CC} = 30 V	t_f	--	35	ns

(1) Pulse Test: Pulse width = 300 μs, duty cycle = 2%

2N3506, 2N3507 (continued)

CURRENT GAIN CHARACTERISTICS



2N3508 (SILICON)
2N3509

NPN silicon annular transistor for high-speed, low-current switching applications.

CASE 26
(TO-46)
Collector connected to case

MAXIMUM RATINGS

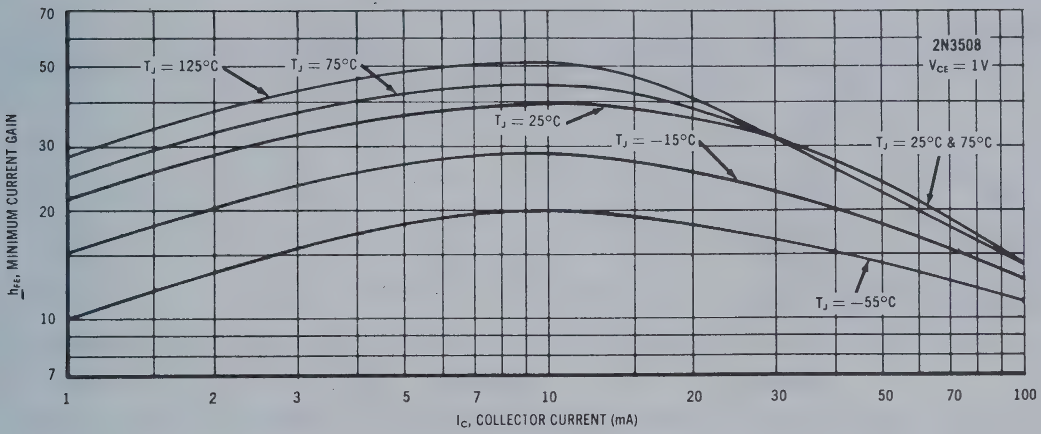
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current (10 μs pulse)	$I_{C(Peak)}$	500	mA
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.40 2.29	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	2.0 11.43	Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Thermal Resistance, Junction to Case Thermal Resistance, Junction to Ambient	θ_{JC} θ_{JA}	0. 438 0. 0875	°C/mW °C/mW

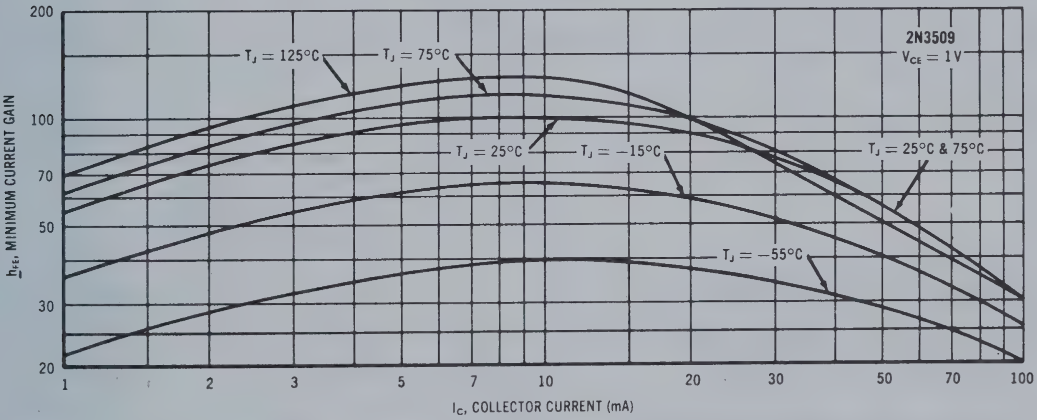
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 20 Vdc)	Both Types		—	0.2	
(V_{CB} = 20 Vdc, T_A = 150°C)	2N3508		—	30	
	2N3509		—	50	
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)		I_{CEX}	—	0.2	μAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)		I_{BL}	—	0.5	μAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_B = 0)		BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6.0	—	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc)		BV_{CEO}	20	—	Vdc
Collector-Emitter Voltage (I_C = 10 μAdc, I_B = 0)		BV_{CES}	40	—	Vdc
Collector-Emitter Saturation Voltage (1)		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)			—	0.45	
Base-Emitter Saturation Voltage (1)		$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			0.70	0.85	
(I_C = 100 mAdc, I_B = 10 mAdc)			0.8	1.4	
DC Current Gain (1)		h_{FE}			—
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3508		40	120	
	2N3509		100	300	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	2N3508		20	—	
	2N3509		40	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3508		20	—	
	2N3509		30	—	
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		h_{fe}	5.0	—	—
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	—	4.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 140 kHz)		C_{ib}	—	4.0	pF
Storage Time (I_C = I_{B1} = I_{B2} = 10 mA)		$t_s(\tau_s)$	—	13	ns
Turn-On Time (I_C = 10 mA, I_{B1} = 3 mA, V_{CC} = 3 V, V_{OB} = 1.5 V)		t_{on}	—	12	ns
Turn-Off Time (I_C = 10 mA, I_{B1} = 3 mA, I_{B2} = 1.5 mA, V_{CC} = 3 V)		t_{off}	—	18	ns
Total Control Charge (I_C = 10 mA, I_B = 1 mA, V_{CC} = 3 V)		Q_T	—	50	pC
Delay Time	V_{CC} = 10 V, V_{EB} = 2 V, I_C = 100 mA, I_{B1} = 10 mA	t_d	—	5.0	ns
Rise Time		t_r	—	18	ns
Storage Time	V_{CC} = 10 V I_C = 100 mA, I_{B1} = I_{B2} = 10 mA	t_s	—	13	ns
Fall Time		t_f	—	15	ns

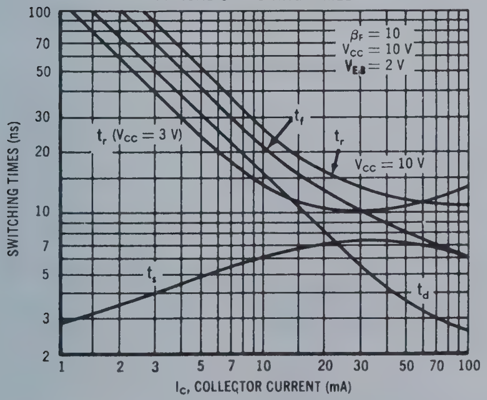
(1) Pulse Test: PW = 300μs, Duty Cycle ≤ 2%

MINIMUM CURRENT GAIN CHARACTERISTICS

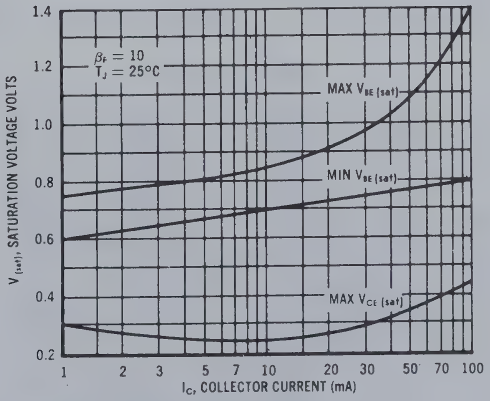




TYPICAL SWITCHING TIMES

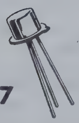


LIMITS OF SATURATION VOLTAGE



2N3510 (SILICON)
2N3511
2N3647
2N3648

NPN silicon annular transistors for high-speed saturated switching applications to 500 mA.



2N3510
2N3511

CASE 27
(TO-52)

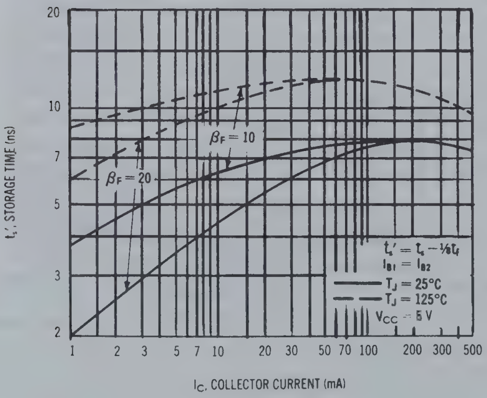
2N3647
2N3648

CASE 26
(TO-46)

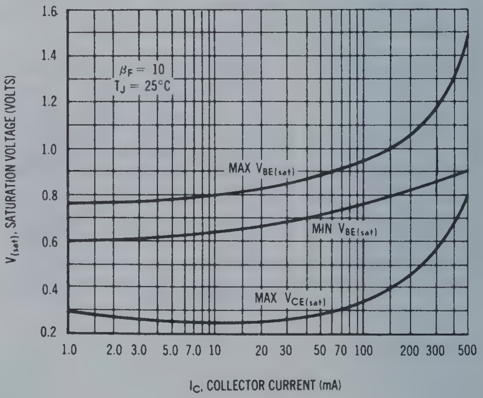
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3510 2N3647	2N3511 2N3648	Unit
Collector-Base Voltage	V_{CB}	40	40	Vdc
Collector-Emitter Voltage	V_{CEO}	10	15	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	500		mAdc
		TO-46 2N3647 2N3648	TO-52 2N3510 2N3511	
Total Device Dissipation @T_A = 25°C Derating Factor Above 25°C	P_D	400 2.28	360 2.06	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	2.0 11.43	1.2 6.9	Watts mW/°C
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C



STORAGE TIME VARIATION



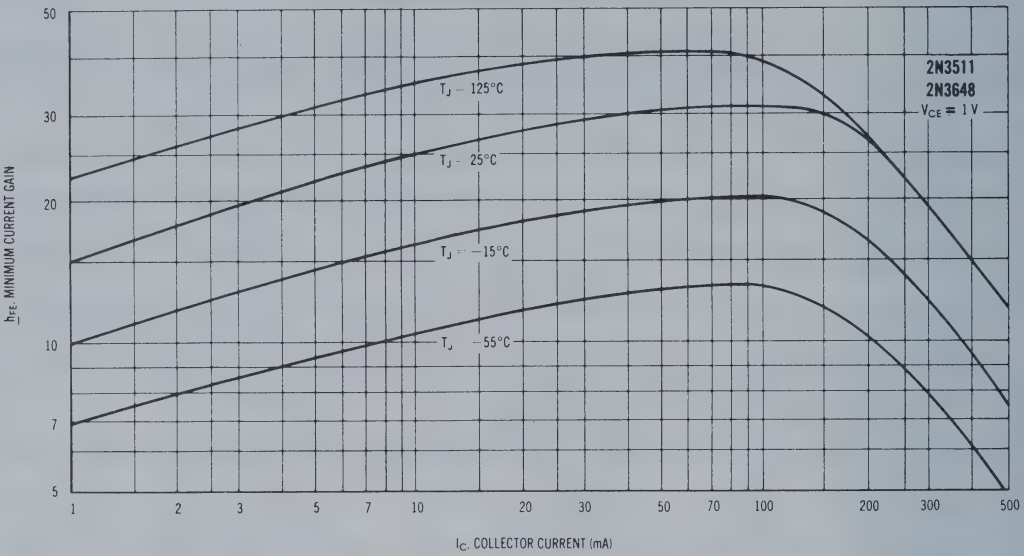
LIMITS OF SATURATION VOLTAGE

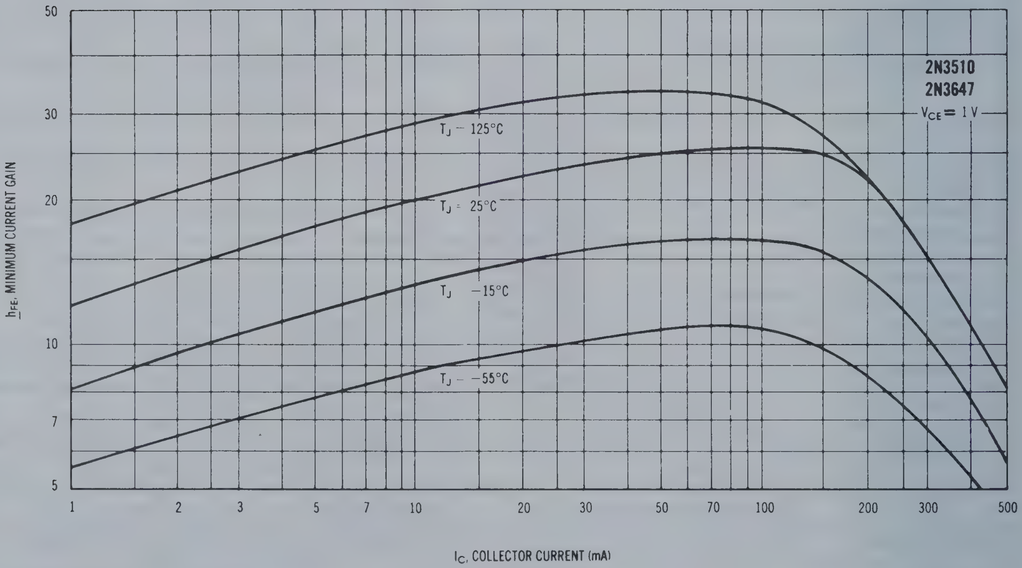
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic			Symbol	Min	Max	Unit
Collector Cutoff Current			I_{CEX}			μAdc
	(V_{CE} = 10 Vdc, $V_{EB(off)}$ = 1 Vdc)			—	.025	
	(V_{CE} = 10 Vdc, $V_{EB(off)}$ = 1 Vdc, T_A = 150°C)			—	50	
Base Cutoff Current			I_{BL}			μAdc
	(V_{CE} = 10 Vdc, V_{OB} = 1 Vdc)			—	.025	
Collector-Base Breakdown Voltage			BV_{CBO}			Vdc
	(I_C = 10 μAdc, I_E = 0)			40	—	
Collector-Emitter Breakdown Voltage*			BV_{CEO}*			Vdc
	(I_C = 10 mAdc, I_B = 0)	2N3510, 2N3647		10	—	
		2N3511, 2N3648		15	—	
Emitter-Base Breakdown Voltage			BV_{EBO}			Vdc
	(I_E = 10 μAdc, I_C = 0)			6.0	—	
Collector Saturation Voltage*			$V_{CE(sat)}$*			Vdc
	(I_C = 10 mAdc, I_B = 1 mAdc)	All Types		—	0.25	
	(I_C = 150 mAdc, I_B = 15 mAdc)	All Types		—	0.4	
	(I_C = 300 mAdc, I_B = 30 mAdc)	2N3510, 2N3647		—	0.6	
	(I_C = 500 mAdc, I_B = 50 mAdc)	2N3511, 2N3648		—	0.8	
Base-Emitter Saturation Voltage*			$V_{BE(sat)}$*			Vdc
	(I_C = 10 mAdc, I_B = 1 mAdc)	All Types		—	0.8	
	(I_C = 150 mAdc, I_B = 15 mAdc)	All Types		0.8	1.0	
	(I_C = 300 mAdc, I_B = 30 mAdc)	2N3510, 2N3647		—	1.15	
	(I_C = 500 mAdc, I_B = 50 mAdc)	2N3511, 2N3648		—	1.5	
DC Current Gain*			h_{FE}*			—
	(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		12	—	
		2N3511, 2N3648		15	—	
	(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		20	—	
		2N3511, 2N3648		25	—	
	(I_C = 150 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		25	150	
		2N3511, 2N3648		30	120	
	(I_C = 150 mAdc, V_{CE} = 1 Vdc, TA = -55°C)	2N3511, 2N3648		12	—	
	(I_C = 300 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		15	—	
	(I_C = 500 mAdc, V_{CE} = 1 Vdc)	2N3511, 2N3648		12	—	
Output Capacitance			C_{ob}			pF
	(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)			—	4.0	
Input Capacitance			C_{ib}			pF
	(V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)			—	8.0	
Small Signal Current Gain			h_{fe}			—
	(I_C = 15 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3510, 2N3647		3.5	—	
		2N3511, 2N3648		4.5	—	
Delay Time	(I_C = 150 mA, I_{B1} = 15 mA, V_{EB} = 0.5 V, V_{CC} = 6 V)	2N3510, 2N3647	t_d	—	10	ns
		2N3511, 2N3648		—	8.0	
Rise Time		2N3510, 2N3647	t_r	—	12	ns
		2N3511, 2N3648		—	10	
Turn-On Time		2N3510, 2N3647	t_{on}	—	20	ns
		2N3511, 2N3648		—	16	
Storage Time	(I_C = 150 mA, I_{B1} = $-I_{B2}$ = 15 mA, V_{CC} = 6 V)	2N3510, 2N3647	t_s	—	16	ns
		2N3511, 2N3648		—	12	
Fall Time		2N3510, 2N3647	t_f	—	12	ns
		2N3511, 2N3648		—	8.0	
Turn-Off Time		2N3510, 2N3647	t_{off}	—	25	ns
		2N3511, 2N3648		—	18	
Total Control Charge			Q_T			pC
	(I_C = 150 mA, I_B = 15 mA, V_{CC} = 6 V)			—	300	
Small Signal Current Gain			h_{fe}			—
	(I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)			20	150	
Voltage Feedback Ratio			h_{re}			X10^{-4}
	(I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)			—	25	
Input Impedance			h_{ie}			kohms
	(I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)			0.6	4.5	
Output Admittance			h_{oe}			μmhos
	(I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)			10	100	

* Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

MINIMUM CURRENT GAIN CHARACTERISTICS





2N3544 (SILICON)

CASE 22
(TO-18)

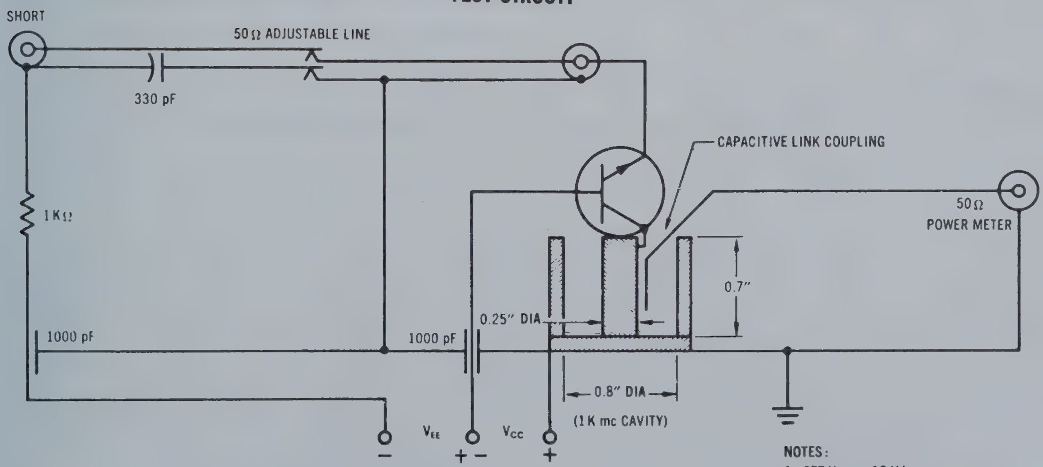
Collector connected to case

NPN silicon annular transistor for VHF and UHF oscillator applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mA
Power Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	400 2.67	mW mW/°C
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

TEST CIRCUIT

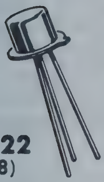

SHORT
50 Ω ADJUSTABLE LINE
330 pF
1 KΩ
1000 pF
1000 pF
CAPACITIVE LINK COUPLING
50 Ω
POWER METER
0.7″
0.25″ DIA
0.8″ DIA
(1 K mc CAVITY)
V_EE
V_CC
−
+ −
+

NOTES:
1. SET $V_{CC} = 12$ Vdc.
2. ADJUST V_{EE} FOR $I_C = 12$ mAdc.
3. SET ADJUSTABLE LINE FOR MAXIMUM POWER OUTPUT.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 10 μAdc, I_E = 0	25	30	--	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 10 μA, V_{BE} = 0	25	30	--	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc, I_E = 0	--	0.01	0.1	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 3 Vdc, I_C = 0	--	0.1	10	μAdc
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C=10 mAdc	25	50	--	--
AC Current Gain	$\lvert h_{fe}\rvert$	V_{CE} = 10 Vdc, I_C =10 mAdc, f = 100 MHz	6.0	9.0	15	--
Collector Output Capacitance	C_{ob}	V_{CB} = 15 Vdc, I_E = 0, f = 100 kHz	--	--	2.5	pF
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 10 mAdc, f = 31.8 MHz	--	--	10	ps
Oscillator Power Output	P_{out}	f = 1.0 GHz, V_C = 12 Vdc, I_C= 12 mAdc	10	16	--	mW

2N3546 (SILICON)



CASE 22
(TO-18)

Collector connected to case

PNP silicon annular transistor for low-level, high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Thermal Resistance, Junction to Ambient	θ_{JA}	0.49	°C/mW
Thermal Resistance, Junction to Case	θ_{JC}	0.15	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current	(V_{CB} = 10 Vdc)	I_{CBO}	--	0.010	µAdc
	(V_{CB} = 10 Vdc, T_A = 150°C)		--	10	
Collector Cutoff Current	(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 3 Vdc)	I_{CEX}	--	0.010	µAdc
Base Cutoff Current	(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 3 Vdc)	I_{BL}	--	0.10	µAdc
Collector-Base Breakdown Voltage	(I_C = 10 µAdc, I_E = 0)	BV_{CBO}	15	--	Vdc
Emitter-Base Breakdown Voltage	(I_E = 10 µAdc, I_C = 0)	BV_{EBO}	4.5	--	Vdc
Collector-Emitter Breakdown Voltage (1)	(I_C = 10 mAdc, I_B = 0)	BV_{CEO}	12	--	Vdc
Collector Saturation Voltage (1)	(I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	--	0.15	Vdc
	(I_C = 50 mAdc, I_B = 5 mAdc)		--	0.25	
	(I_C = 100 mAdc, I_B = 10 mAdc)		--	0.50	
Base-Emitter Saturation Voltage (1)	(I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.7	0.9	Vdc
	(I_C = 50 mAdc, I_B = 5 mAdc)		0.8	1.3	
	(I_C = 100 mAdc, I_B = 10 mAdc)		--	1.6	
DC Current Gain (1)	(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)	h_{FE}	20	--	--
	(I_C = 10 mAdc, V_{CE} = 1 Vdc)		30	120	
	(I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C)		15	--	
	(I_C = 50 mAdc, V_{CE} = 1 Vdc)		25	--	
	(I_C = 100 mAdc, V_{CE} = 1Vdc)		15	--	
Output Capacitance	(V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	--	6.0	pF
Input Capacitance	(V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)	C_{ib}	--	5.0	pF
Current-Gain - Bandwidth Product	(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	700	--	MHz
Total Control Charge	(I_C = 50 mA, I_B = 5 mA, V_{CC} = 3 V)	Q_T	--	400	pC
Delay Time	I_C = 50 mA, I_{B1} = 5mA, V_{BE} = 2 V, V_{CC} = 3 V	t_d	--	10	ns
Rise Time		t_r	--	15	ns
Storage Time	I_C = 50 mA, I_{B1} = I_{B2} = 5 mA, V_{CC} = 3 V	t_s	--	20	ns
Fall Time		t_f	--	15	ns
Turn-On Time	(See Figure 3,4,5)	t_{on}	--	40	ns
Turn-Off Time		t_{off}	--	30	ns

(1) Pulse Test: PW = 300 µs, Duty Cycle ≤ 2%

FIGURE 1

LIMITS OF SATURATION VOLTAGES

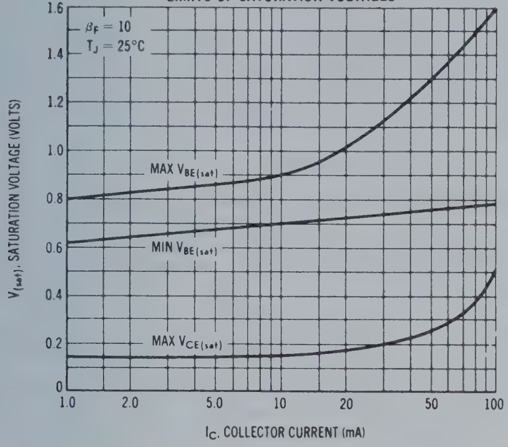


FIGURE 2

STORAGE TIME BEHAVIOR

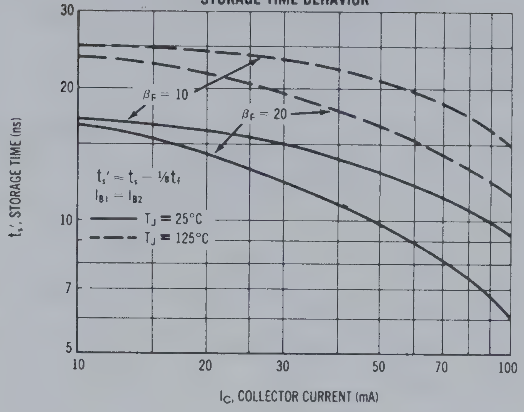
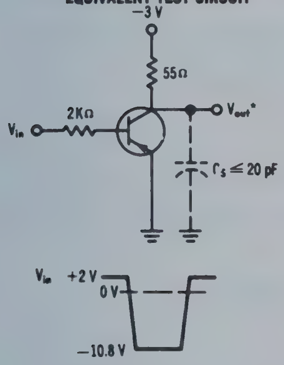


FIGURE 3

DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

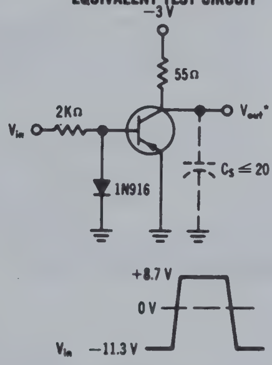

−3 V
55Ω
2KΩ
V_{in}
V_{out}*
$C_S \leq 20$ pF
V_{in}
+2 V
0 V
−10.8 V

PULSE WIDTH = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 10%

*OSCILLOSCOPE RISE TIME ≤ 1 ns

FIGURE 4

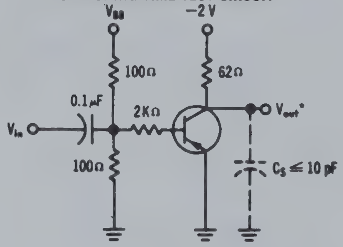
STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT


−3 V
55Ω
2KΩ
V_{in}
V_{out}*
1N916
$C_S \leq 20$ pF
+8.7 V
0 V
V_{in}
−11.3 V

PULSE WIDTH = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 10%

FIGURE 5

SWITCHING TIME TEST CIRCUIT

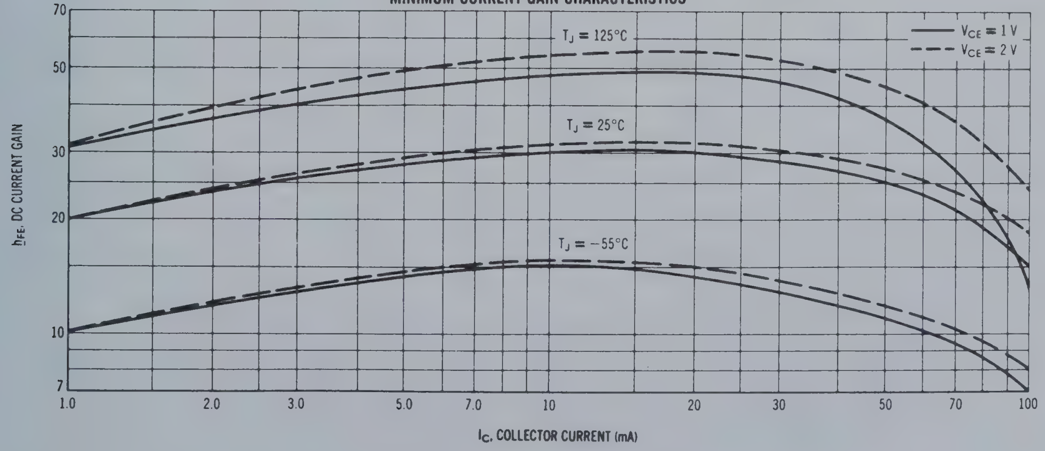

V_{BB}
−2 V
100Ω
62Ω
0.1 μF
2KΩ
V_{in}
100Ω
V_{out}*
$C_S \leq 10$ pF

PULSE WIDTH > 200 ns
RISE TIME < 1 ns
Z_{in} = 50Ω

t_{on} : V_{BB} = +3 V, V_{in} = −7 V
t_{off} : V_{BB} = −4 V, V_{in} = +6 V

FIGURE 6

MINIMUM CURRENT GAIN CHARACTERISTICS

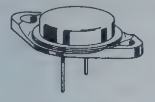


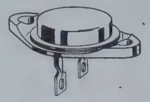
2N3553 (SILICON)

For Specifications, See 2N3375 Data.

2N3611 thru 2N3614 (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications.


CASE 11
(TO-3)

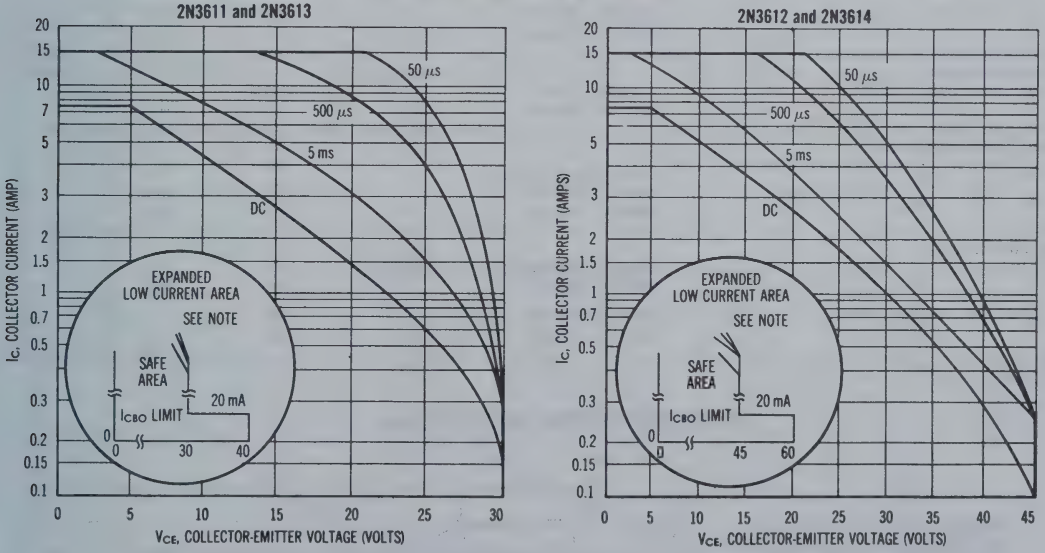

CASE 4-04
(TO-41)

For units with solder lugs attached, specify device MP3611 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N3611 2N3613	2N3612 2N3614	Unit
Collector-Emitter Voltage	V_{CES}	30	45	Vdc
Collector-Emitter Voltage (Open Base)	V_{CEO}	25	35	Vdc
Collector-Base Voltage	V_{CB}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	20	30	Vdc
Collector Current (Continuous)	I_C	7.0		Adc
Peak Collector Current (PW ≦ 5 msec)	I_C	15		Adc
Base Current (Continuous)	I_B	2.0		Adc
Storage Temperature Range	T_{stg}	-65 to +110		°C
Operating Case Temperature Range	T_C	-65 to +110		°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above $T_C = 25^oC$	P_D	77 1.0		Watts W/°C
Thermal Resistance, Junction to Case	θ_{JC}	1.1		°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	32.7		°C/W

SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CES} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

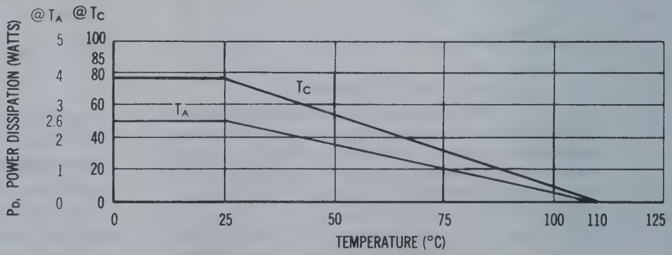
ELECTRICAL CHARACTERISTICS

Characteristics		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 250 mAdc)	2N3611, 2N3613	BV_{CES}*	30	–	Vdc
	2N3612, 2N3614		45	–	
Collector-Emitter Breakdown Voltage* (I_C = 500 mAdc)	2N3611, 2N3613	BV_{CEO}*	25	–	Vdc
	2N3612, 2N3614		35	–	
Floating Potential (V_{CB} = V_{CB} max)		V_{EBF}	–	1.0	Vdc
Collector-Emitter Leakage Current (V_{CE} = 1/2 V_{CEO} max)		I_{CEO}	–	30	mAdc
Collector-Emitter Leakage Current (V_{CE} = V_{CE} max, V_{BE} = 1.0 Vdc, T_C = +100°C)		I_{CEX}	–	10	mAdc
Collector-Base Cutoff Current (V_{CB} = 2 Vdc)		I_{CBO}	–	.040	mAdc
(V_{CB} = 25 Vdc)	2N3611, 2N3613		–	0.5	
(V_{CB} = 40 Vdc)	2N3612, 2N3614		–	0.5	
(V_{CB} = V_{CB} max)			–	5.0	
Emitter-Base Cutoff Current (V_{EB} = V_{EB} max)		I_{EBO}	–	500	μAdc
Collector-Emitter Saturation Voltage (I_C = 3 Adc, I_B = 300 mAdc)		$V_{CE(sat)}$	–	0.25	Vdc
(I_C = 7 Adc, I_B = 700 mAdc)			–	0.35	
Base-Emitter Saturation Voltage (I_C = 3 Adc, I_B = 300 mAdc)	2N3611, 2N3612	$V_{BE(sat)}$	–	0.7	Vdc
	2N3613, 2N3614		–	0.6	
(I_C = 7 Adc, I_B = 700 mAdc)	2N3611, 2N3612		–	1.1	
	2N3613, 2N3614		–	0.9	
Transconductance (I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612	g_{FE}	3.0	–	mhos
	2N3613, 2N3614		3.5	–	
Small Signal Current Gain (I_C = 0.5 A, V_{CE} = 12 V, f = 20 kHz)		h_{fe}	15	–	–
(I_C = 0.5 A, V_{CE} = 2 V, f = 1 kHz)	2N3611, 2N3612		40	100	
	2N3613, 2N3614		60	150	
DC Current Gain (I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612	h_{FE}	35	70	–
	2N3613, 2N3614		60	120	
(I_C = 7 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612		20	–	
	2N3613, 2N3614		30	–	

*Sweep Test: 1/2 sine wave, 60 Hz

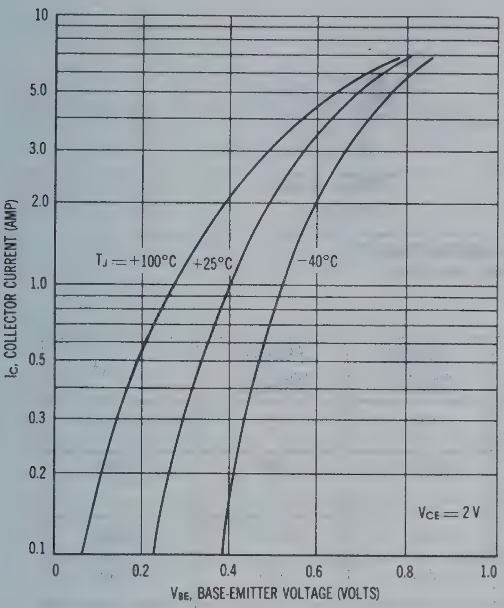
POWER-TEMPERATURE DERATING CURVE

These transistors are also subject to safe area curves. Both limits are applicable and must be observed.

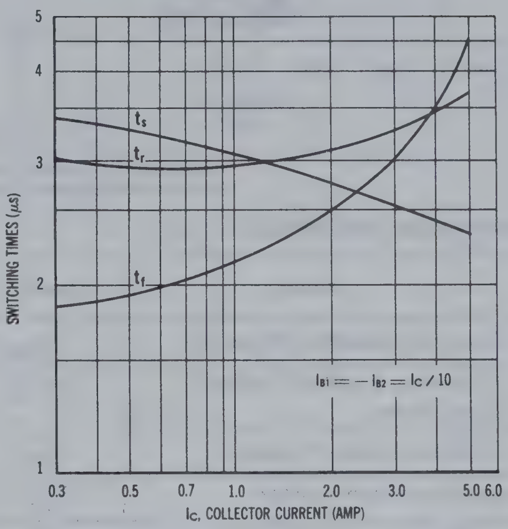


2N3611 thru 2N3614 (continued)

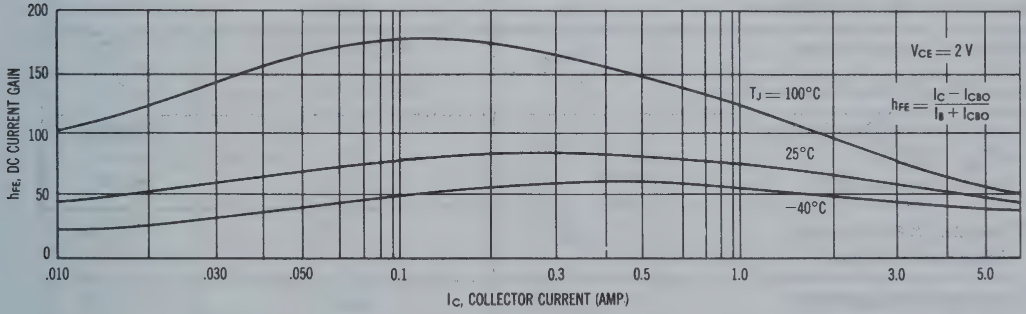
COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE



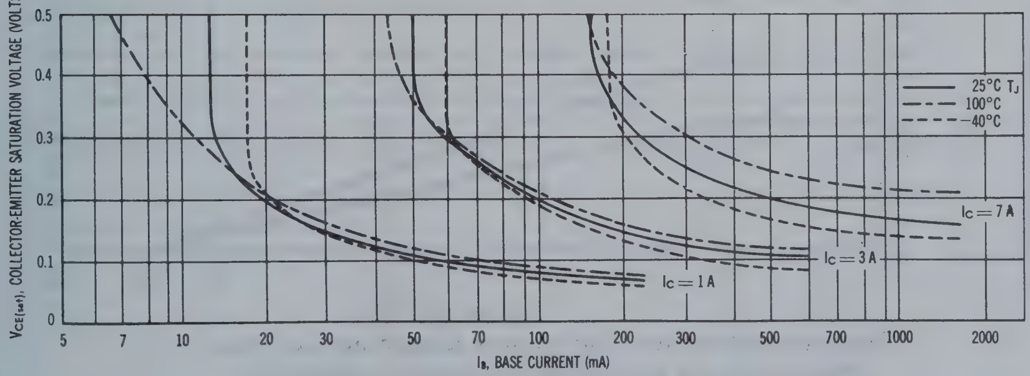
TYPICAL SWITCHING TIMES



DC CURRENT GAIN versus COLLECTOR CURRENT

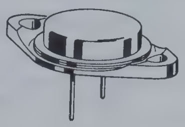


COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

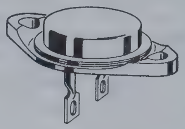


2N3615 thru 2N3618 (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications.



CASE 11
(TO-3)

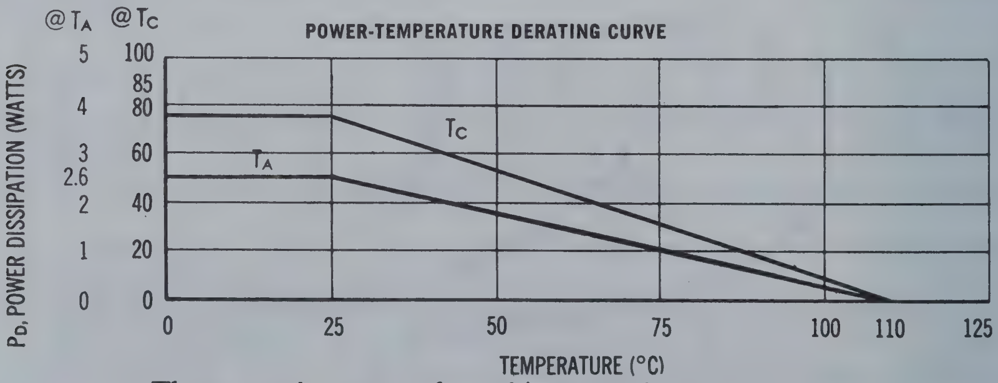


CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP3615 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N3615 2N3617	2N3616 2N3618	Unit
Collector-Emitter Voltage	V_{CES}	60	75	Vdc
Collector-Emitter Voltage (Open Base)	V_{CEO}	50	60	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	40	50	Vdc
Collector Current (Continuous)	I_C	7.0		Adc
Peak Collector Current (PW ≦ 5 msec)	I_C	15		Adc
Base Current (Continuous)	I_B	2.0		Adc
Storage Temperature	T_{stg}	-65 to +110		°C
Operating Case Temperature	T_C	-65 to +110		°C
Total Device Dissipation @T_C = 25°C Derate above 25°C	P_D	 77 1.0		Watts W/°C
Thermal Resistance, Junction to Case	θ_{JC}	1.0		°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	32.7		°C/W



These transistors are also subject to safe area curves. Both limits are applicable and must be observed.

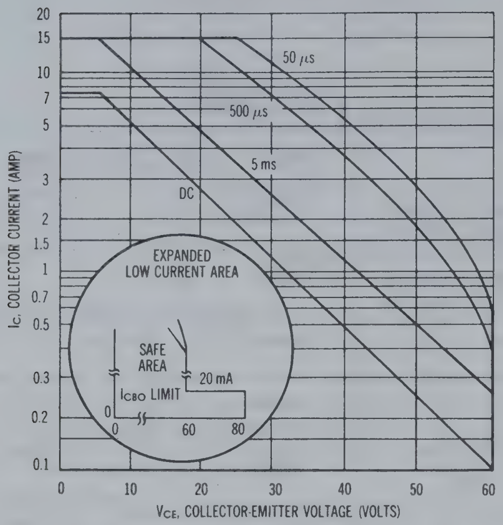
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage*		BV_{CES}*			Vdc
(I_C = 250 mAdc)	2N3615, 2N3617		60	-	
	2N3616, 2N3618		75	-	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 300 mAdc)	2N3615, 2N3617		50	-	
	2N3616, 2N3618		60		
Floating Potential (V_{CB} = V_{CB} max)		V_{EBF}	-	1.0	Vdc
Collector-Emitter Leakage Current (V_{CE} = 1/2 V_{CEO} max)		I_{CEO}	-	30	mAdc
Collector-Emitter Leakage Current (V_{CE} = V_{CE} max, V_{BE} = 1.0 Vdc, T_C = +100°C)		I_{CEX}	-	10	mAdc
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 2.0 Vdc)			-	0.060	
(V_{CB} = 55 Vdc)	2N3615, 2N3617		-	1.0	
(V_{CB} = 65 Vdc)	2N3616, 2N3618		-	1.0	
(V_{CB} = V_{CB} max)			-	5.0	
Emitter-Base Cutoff Current		I_{EBO}			μAdc
(V_{EB} = V_{EB} max)				500	
(V_{EB} = 12 Vdc)			-		
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 300 mAdc)			-	0.25	
(I_C = 7.0 Adc, I_B = 700 mAdc)			-	0.35	
Base Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 300 mAdc)	2N3615, 2N3616		-	0.7	
	2N3617, 2N3618		-	0.6	
(I_C = 7.0 Adc, I_B = 700 mAdc)	2N3615, 2N3616		-	1.1	
	2N3617, 2N3618		-	0.9	
Transconductance		g_{FE}			mhos
(I_C = 3.0 A, V_{CE} = 2.0 V)	2N3615, 2N3616		3.0	-	
	2N3617, 2N3618		3.5	-	
Small Signal Current Gain		h_{fe}			-
(I_C = 0.5 A, V_{CE} = 12 V, f = 20 kHz)			15	-	
(I_C = 0.5 A, V_{CE} = 2.0 V, f = 1.0 kHz)	2N3615, 2N3616		40	100	
	2N3617, 2N3618		60	150	
DC Current Gain		h_{FE}			-
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N3615, 2N3616		30	60	
	2N3617, 2N3618		45	90	
(I_C = 7.0 Adc, V_{CE} = 2.0 Vdc)	2N3615, 2N3616		20	-	
	2N3617, 2N3618		30	-	
Current-Gain–Bandwidth Product		f_T	Typ		kHz
(I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)			600		

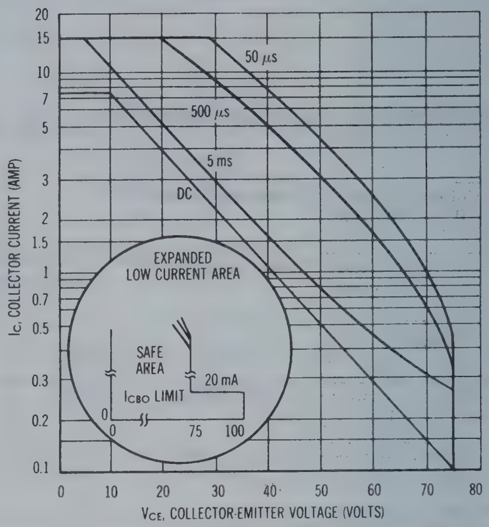
*Sweep Test: 1/2 sine wave, 60 Hz

SAFE OPERATING AREAS

2N3615 and 2N3617

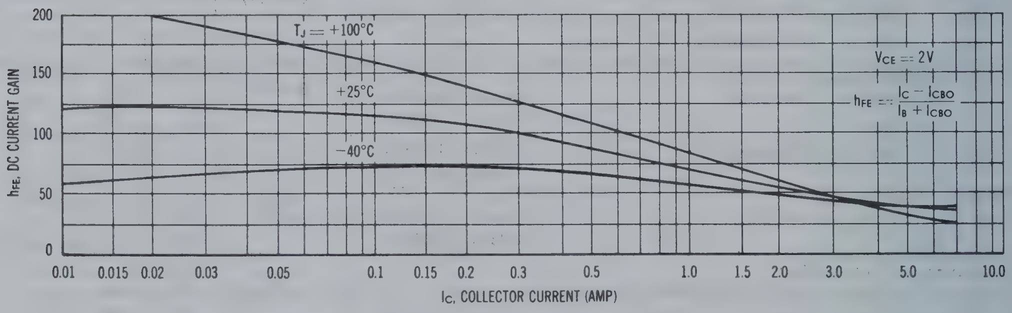


2N3616 and 2N3618

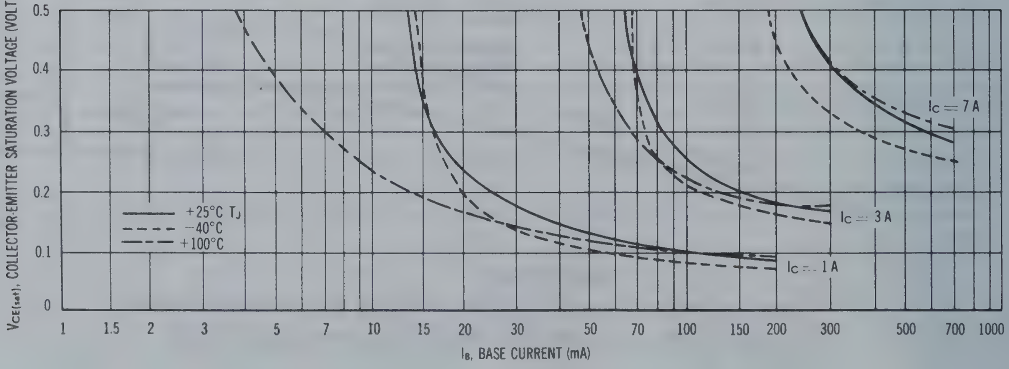


NOTE The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CES} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

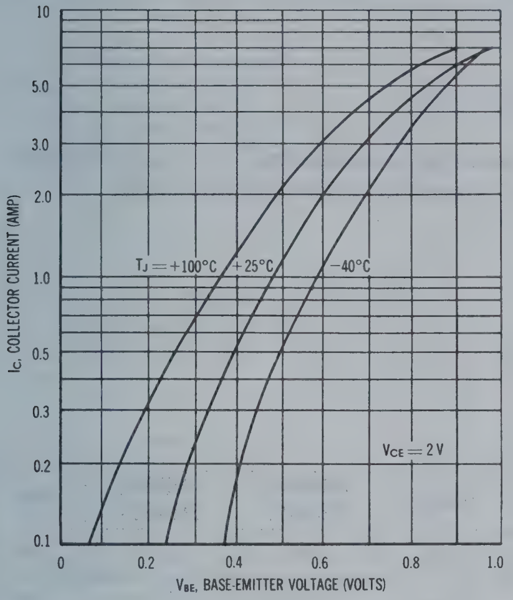
DC CURRENT GAIN versus COLLECTOR CURRENT



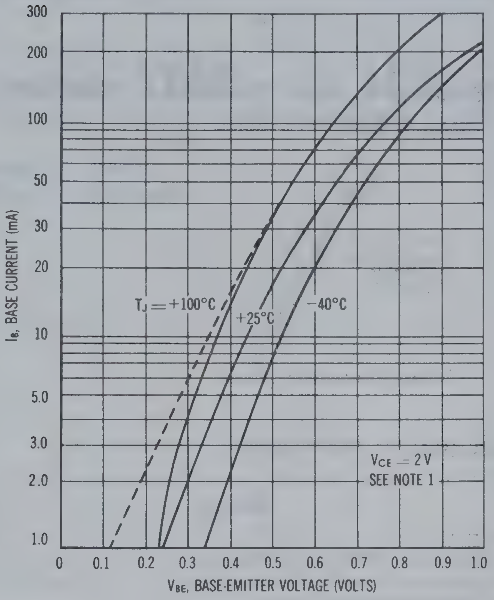
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE



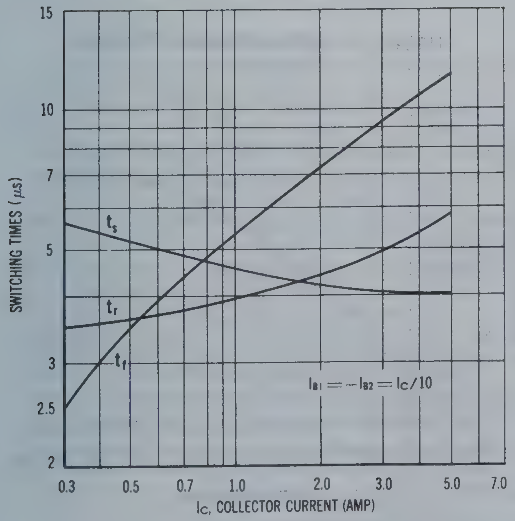
BASE CURRENT versus BASE-EMITTER VOLTAGE

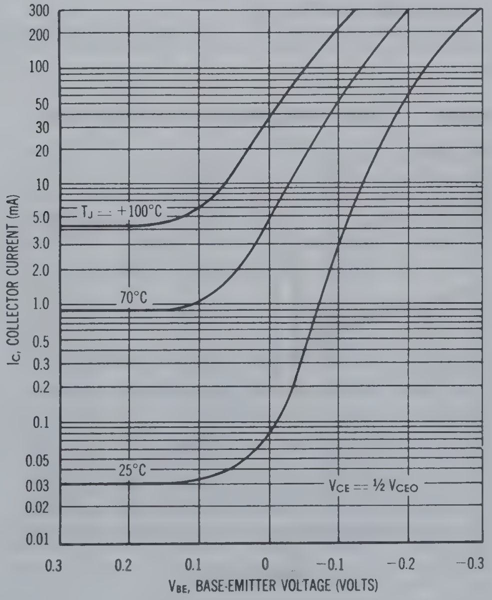


NOTE 1 — Dotted line indicates Metered Base Current plus the I_{CBO} of the transistor at 100°C.

COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

TYPICAL SWITCHING TIMES





2N3632

For Specifications, See 2N3375 Data.

2N3634 thru 2N3637 (SILICON)

JAN, JTX AVAILABLE

CASE 31
(TO-5)

Collector connected to case

PNP silicon annular transistors for high-voltage switching and low-power amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3634 2N3635	2N3636 2N3637	Unit
Collector-Emitter Voltage	V_{CEO}	140	175	Vdc
Collector-Base Voltage	V_{CB}	140	175	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

FIGURE 1 — JUNCTION CAPACITANCE VARIATIONS

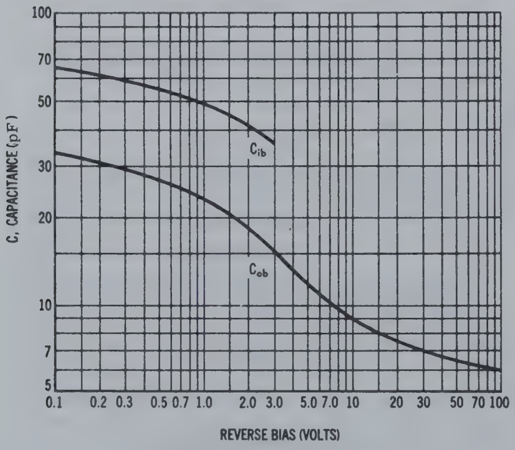
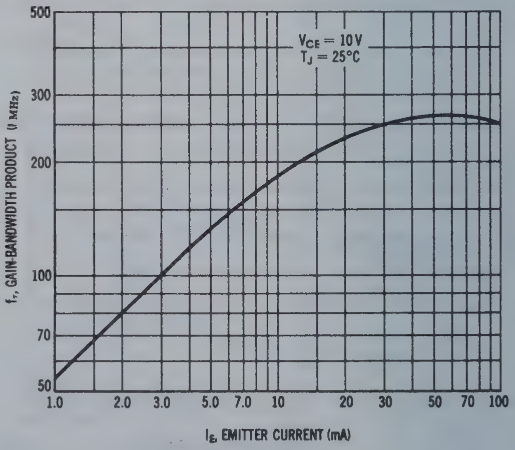


FIGURE 2 — GAIN-BANDWIDTH PRODUCT



2N3634 thru 2N3637 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0) 2N3634, 2N3635 2N3636, 2N3637	-	BV_{CEO}	140 175	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) 2N3634, 2N3635 2N3636, 2N3637	-	BV_{CBO}	140 175	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	-	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 100 Vdc, I_E = 0)	-	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	-	I_{EBO}	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (1) (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 50 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637	3, 4, 5, 6	h_{FE}	40 80 45 90 50 100 50 100 25 50	- - - - - - 150 300 - -	-
Collector-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	11, 12	$V_{CE(sat)}$	- -	0.3 0.5	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	11, 12	$V_{BE(sat)}$	- 0.65	0.8 0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (V_{CE} = 30 Vdc, I_C = 30 mAdc, f = 100 MHz) 2N3634, 2N3636 2N3635, 2N3637	2	f_T	150 200	- -	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	1	C_{ob}	-	10	pF
Input Capacitance (V_{BE} = 1.0 Vdc, I_C = 0, f = 100 kHz)	1	C_{ib}	-	75	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3634, 2N3636 2N3635, 2N3637	7	h_{ie}	100 200	600 1200	ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	10	h_{re}	-	3.0	X 10^{-4}
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3634, 2N3636 2N3635, 2N3637	9	h_{fe}	40 80	160 320	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	8	h_{oe}	-	200	μmhos
Noise Figure (I_C = 0.5 mAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohms, f = 1.0 kHz)	-	NF	-	3.0	dB

SWITCHING CHARACTERISTICS

Turn-On Time	(V_{CC} = 100 Vdc, V_{BE} = 4.0 Vdc, I_C = 50 mAdc, I_{B1} = I_{B2} = 5.0 mAdc)	13, 14	t_{on}	-	400	ns
Turn-Off Time		13, 15	t_{off}	-	600	ns

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

FIGURE 3 — CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

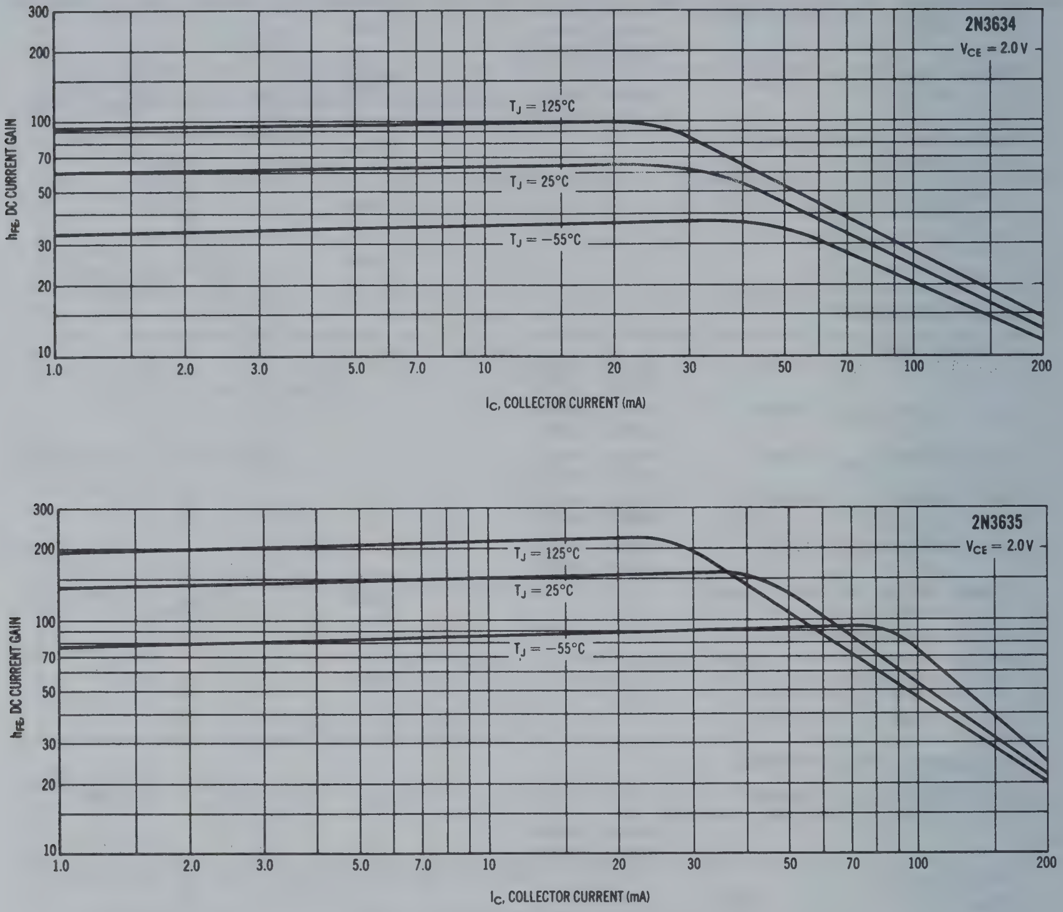


FIGURE 4 — CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE

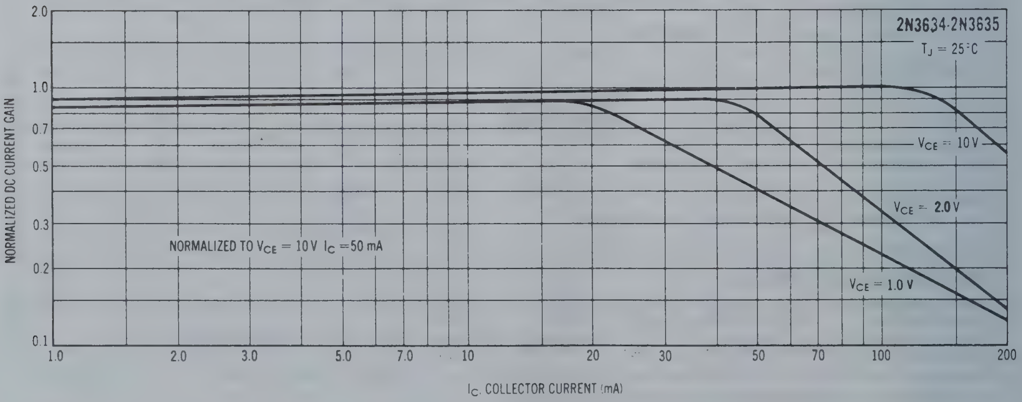


FIGURE 5 — CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

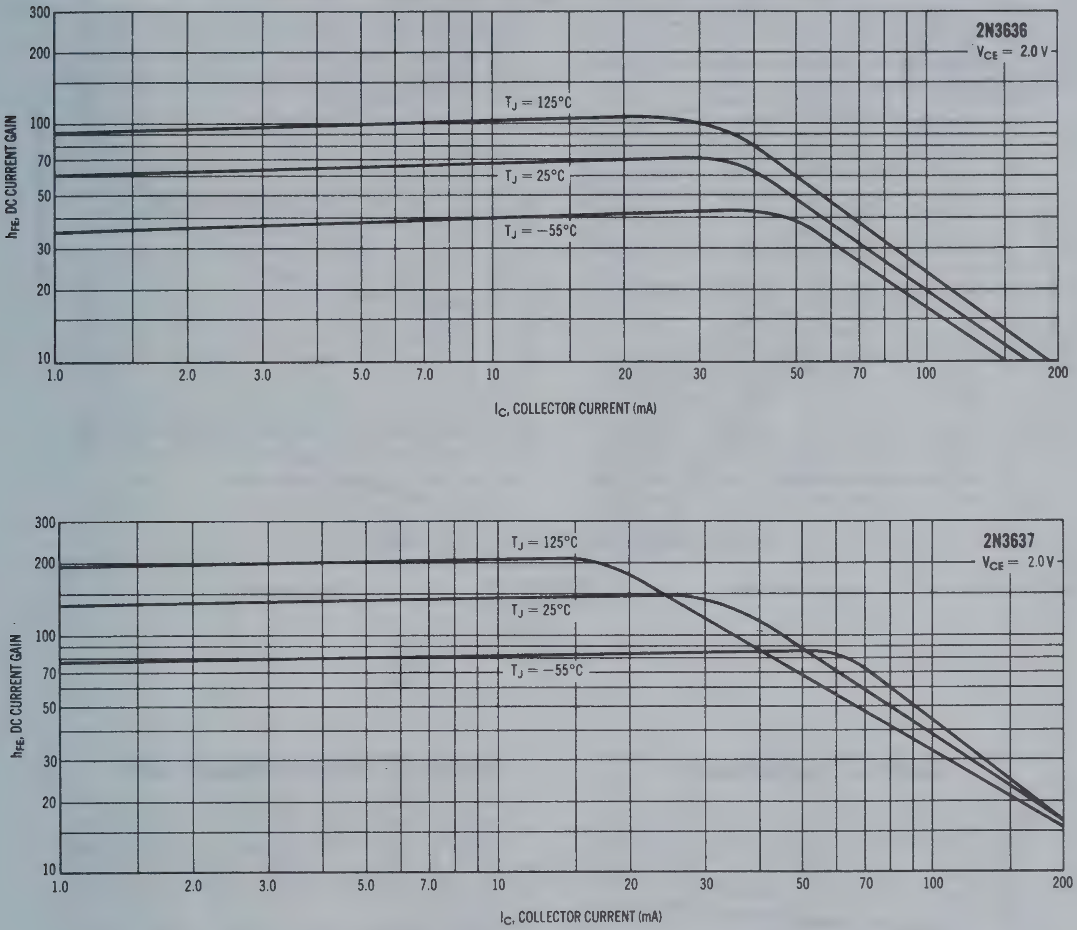
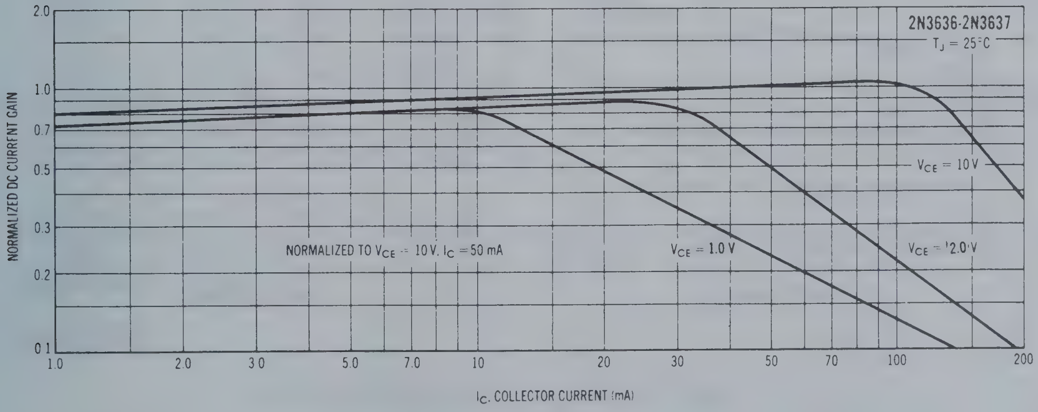


FIGURE 6 — CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE



2N3634 thru 2N3637 (continued)

FIGURE 7 — INPUT IMPEDANCE

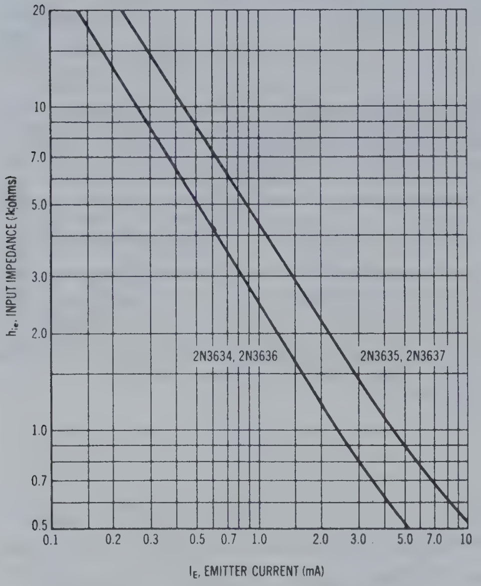


FIGURE 8 — OUTPUT IMPEDANCE

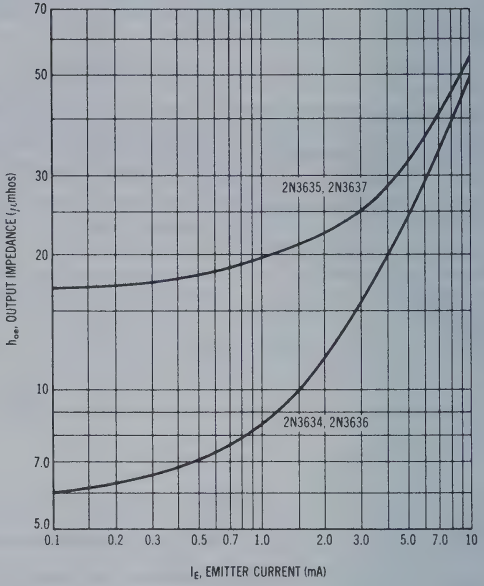


FIGURE 9 — CURRENT GAIN

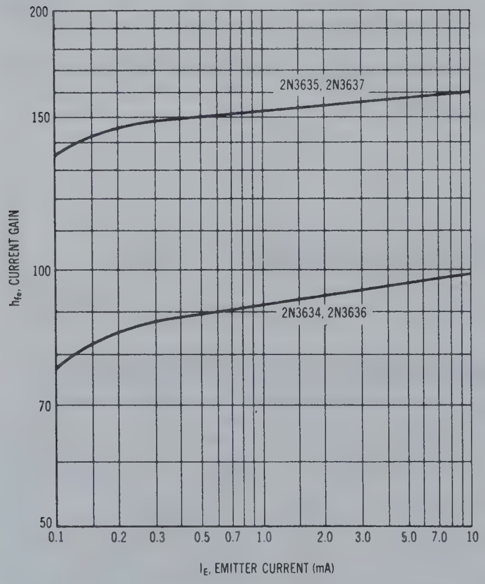


FIGURE 10 — VOLTAGE FEEDBACK RATIO

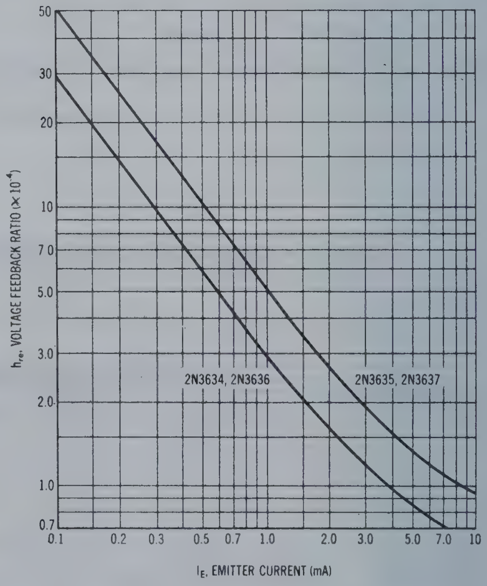


FIGURE 11 — SATURATION VOLTAGES

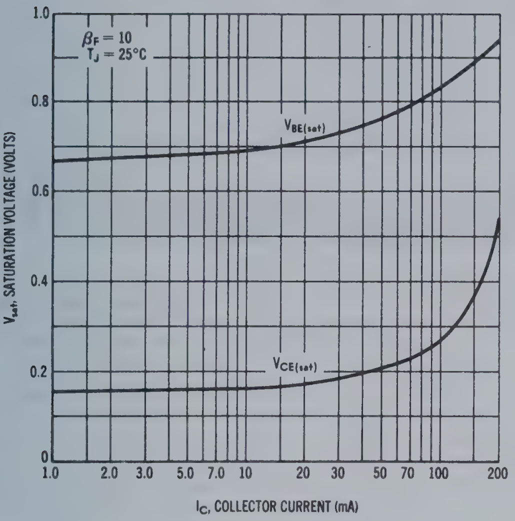


FIGURE 12 — TEMPERATURE COEFFICIENTS

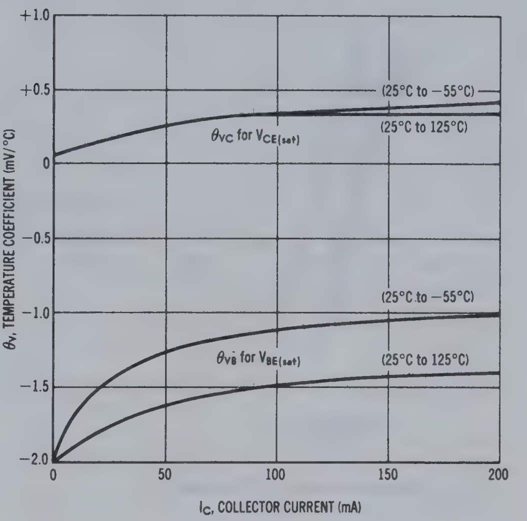
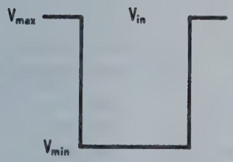


FIGURE 13 — SWITCHING TIME TEST CIRCUIT



P.W. ≃ 20 μs
DUTY CYCLE ≤ 2%
RISE TIME ≤ 20 ns

	V_{max}	V_{min}
TURN-ON	+4.0 V	−5.65 V
TURN-OFF	+4.1 V	−5.9 V

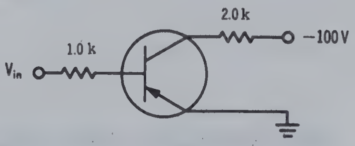


FIGURE 14 — TURN-ON TIME VARIATIONS WITH VOLTAGE

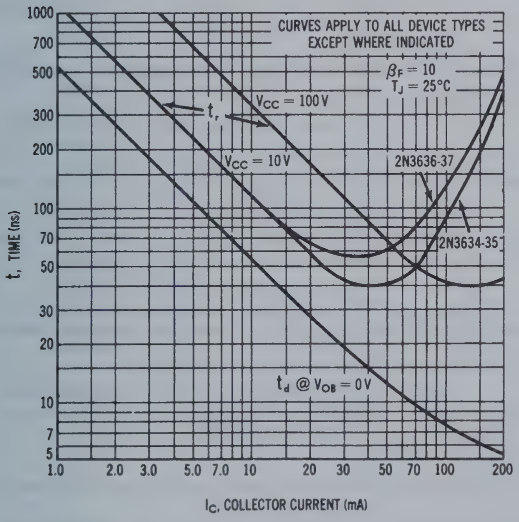
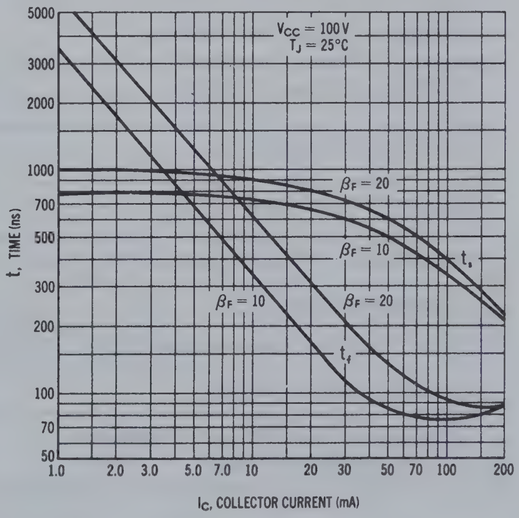


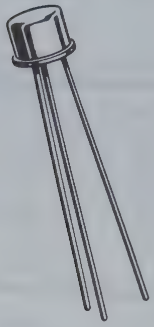
FIGURE 15 — TURN-OFF TIME VARIATIONS WITH CIRCUIT GAIN



2N3647 (SILICON)
2N3648

For Specifications, See 2N3510 Data.

2N3712 (SILICON)



CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-voltage DC to VHF amplifier applications.

MAXIMUM RATINGS

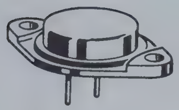
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	150	Vdc
Collector-Base Voltage	V_{CB}	150	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	150	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	150	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0) (V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.1 50	μAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain (1) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25 30	- 150	-
Collector-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	-	2.0	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	40	240	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	1.0	9.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	80	pF
Small-Signal Current Gain (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	-	-
Collector-Base Time Constant (I_E = 30 mAdc, V_{CB} = 10 Vdc, f = 31.9 MHz)	$r_b'C_c$	-	100	ps

(1) Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N3713 thru 2N3716 (SILICON)

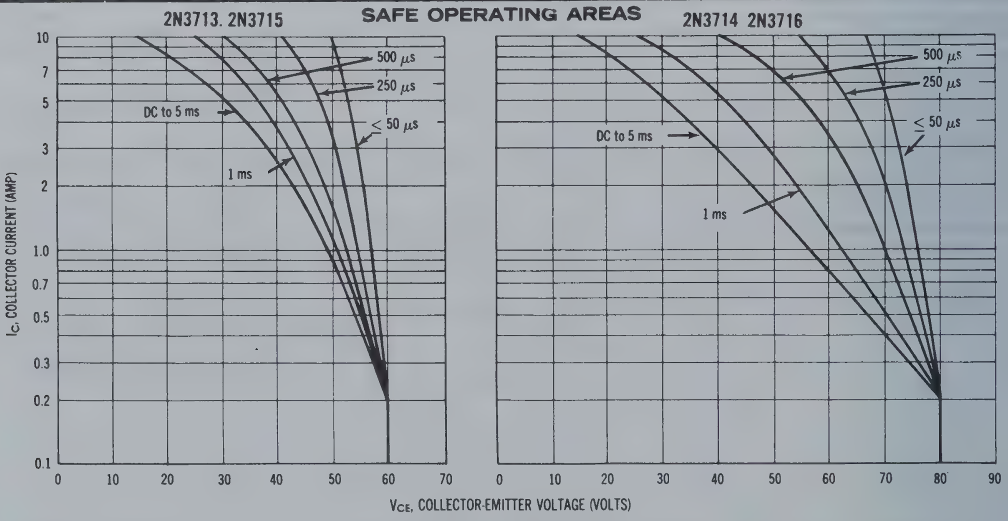


CASE 11
(TO-3)

NPN silicon power transistors for medium-speed switching and amplifier applications. Complement to PNP types 2N3789 thru 2N3792.

MAXIMUM RATINGS

Rating	Symbol	2N3713 2N3715	2N3714 2N3716	Unit
Collector-Base Voltage	V_{CB}	80	100	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	7.0	7.0	Volts
Collector Current	I_C	10	10	Amp
Base Current	I_B	4.0	4.0	Amp
Power Dissipation	P_D	150	150	Watts
Thermal Resistance	Θ_{JC}	1.17	1.17	°C/W
Operating Junction and Storage Temperature Range	T_J and T_{stg}	-65 to +200		°C


SAFE OPERATING AREAS

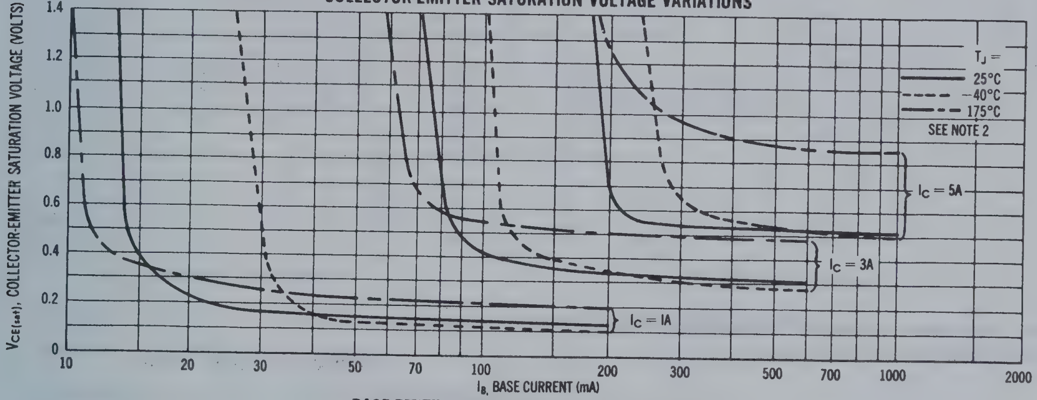
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

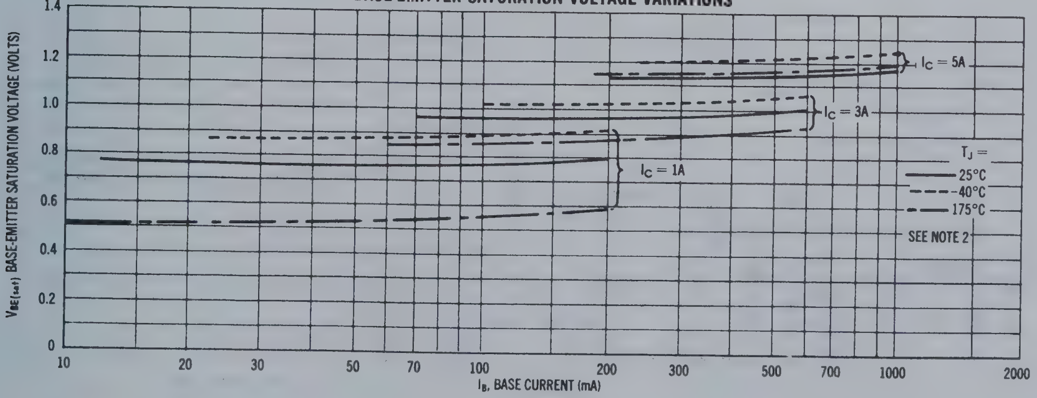
Characteristic	Types	Symbol	Min	Max	Unit
Emitter-Base Cutoff Current (V_{EB} = 7 Vdc)		I_{EBO}	—	5.0	mAdc
Collector-Emitter Cutoff Current (V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc) (V_{CE} = 100 Vdc, V_{BE} = -1.5 Vdc) (V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C) (V_{CE} =80 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3713, 2N3715 2N3714, 2N3716 2N3713, 2N3715 2N3714, 2N3716	I_{CEX}	— — — —	1.0 1.0 10 10	mAdc
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	2N3713, 2N3715 2N3714, 2N3716	$V_{CEO(sus)}$*	60 80	— —	Vdc
DC Current Gain* (I_C = 1 Adc, V_{CE} = 2 Vdc) (I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3713, 2N3714 2N3715, 2N3716 2N3713, 2N3714 2N3715, 2N3716	h_{FE}*	25 50 15 30	90 150 — —	—
Collector-Emitter Saturation Voltage* (I_C = 5 Adc, I_B = 0.5 Adc)	2N3713, 2N3714 2N3715, 2N3716	$V_{CE(sat)}$*	— —	1.0 0.8	Vdc
Base-Emitter Saturation Voltage* (I_C = 5 Adc, I_B = 0.5 Adc)	2N3713, 2N3714 2N3715, 2N3716	$V_{BE(sat)}$*	— —	2.0 1.5	Vdc
Base-Emitter Voltage* (I_C = 3 Adc, V_{CE} = 2 Vdc)		V_{BE}*	—	1.5	Vdc
Small Signal Current Gain (V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 MHz)		h_{fe}	4.0	—	—
Switching Times (I_C = 5A, I_{B1} = I_{B2} = 0.5 A)			Typ		μs
Rise Time		t_r	0.45		
Storage Time		t_s	0.3		
Fall Time		t_f	0.4		

*Use sweep test to prevent overheating

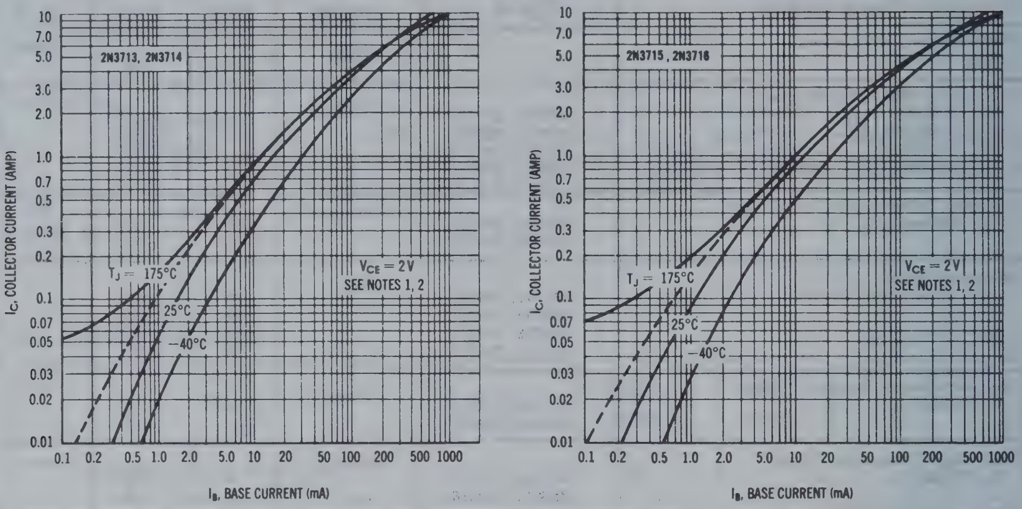
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



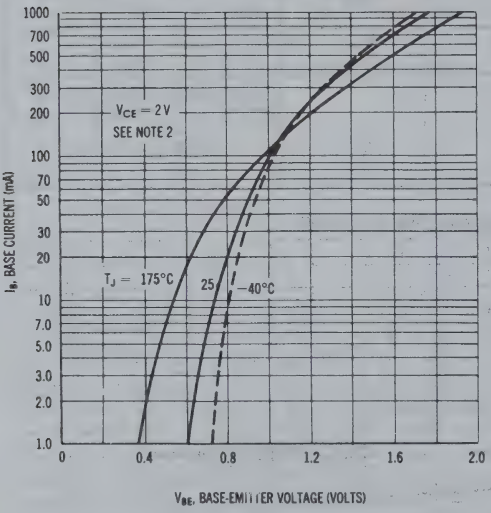
BASE-EMITTER SATURATION VOLTAGE VARIATIONS



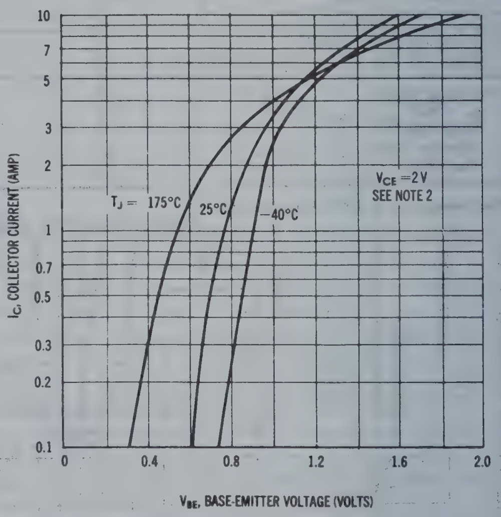
COLLECTOR CURRENT versus BASE CURRENT



BASE CURRENT-VOLTAGE VARIATIONS



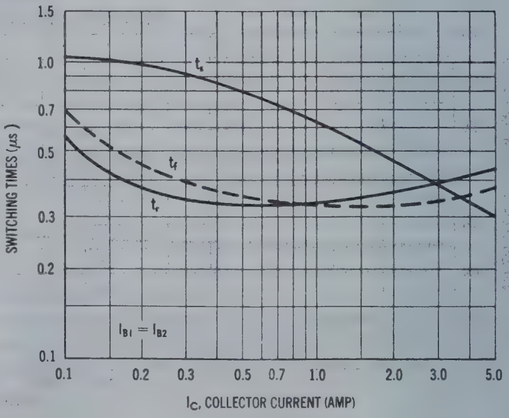
COLLECTOR CURRENT-VOLTAGE VARIATIONS



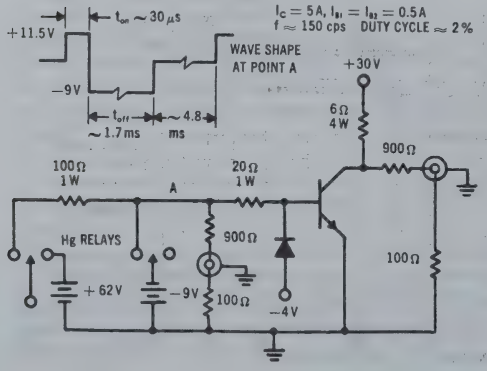
NOTE 1. Dotted line indicates metered base current plus the I_{CBO} of the transistor at 175°C.

NOTE 2. Pulse test: pulse width ≈ 200 μs, duty cycle ≈ 1.5%

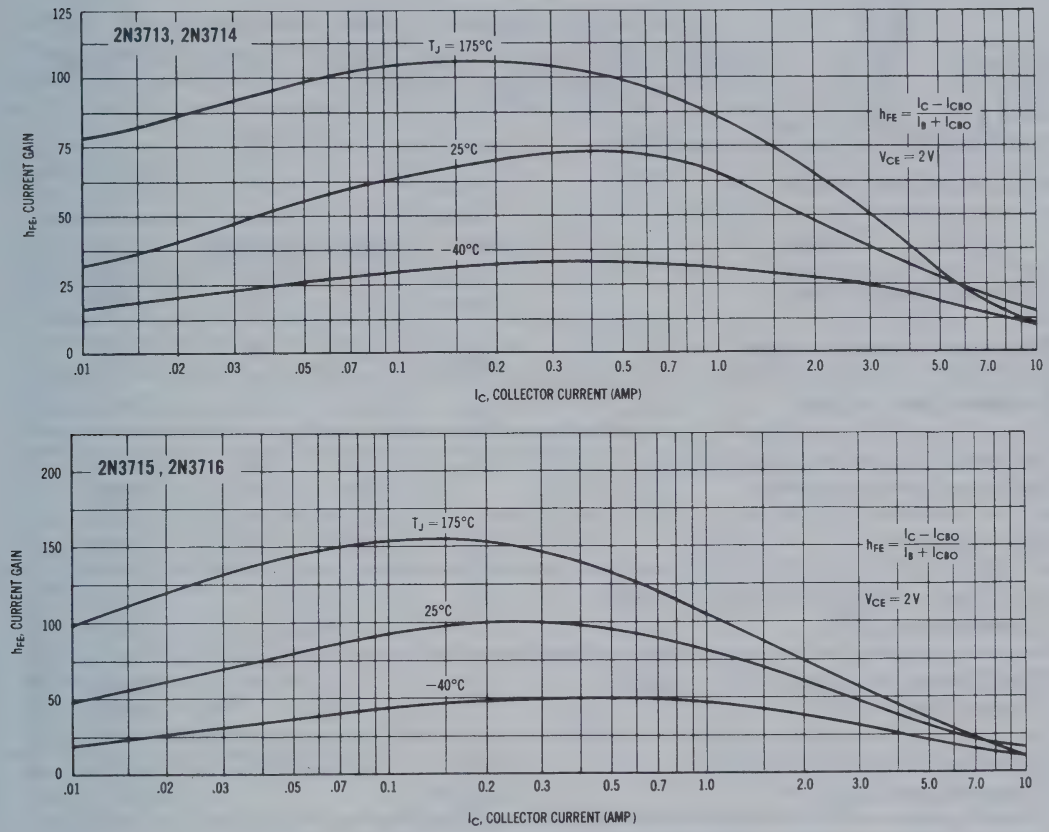
TYPICAL SWITCHING TIMES



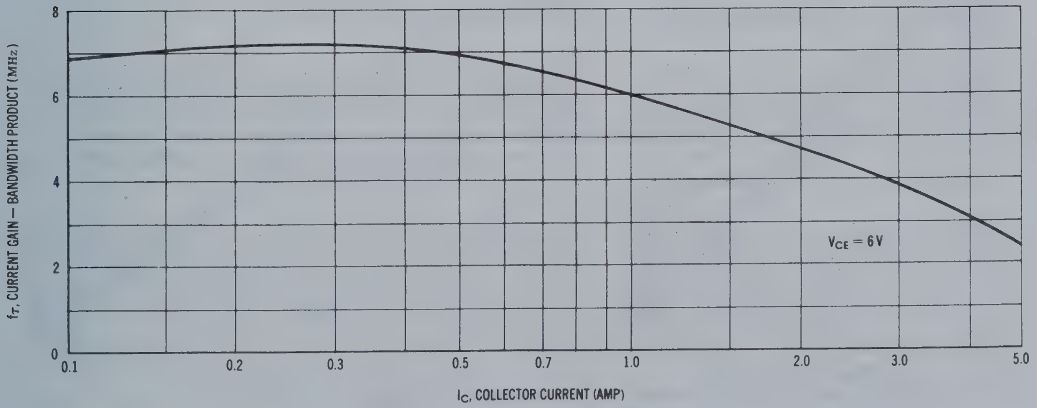
TEST CIRCUIT


I_C = 5 A, I_{B1} = I_{B2} = 0.5 A
f ≈ 150 cps DUTY CYCLE ≈ 2%
t_{on} ~ 30 μs
+11.5V
−9V
t_{off}
~ 1.7 ms
~ 4.8 ms
WAVE SHAPE AT POINT A
+30V
6 Ω 4 W
900 Ω
100 Ω 1 W
A
20 Ω 1 W
Hg RELAYS
900 Ω
100 Ω
+ 62V
−9V
100 Ω
−4V

CURRENT GAIN VARIATIONS



CURRENT-GAIN—BANDWIDTH PRODUCT versus COLLECTOR CURRENT



2N3719 (SILICON)
2N3720

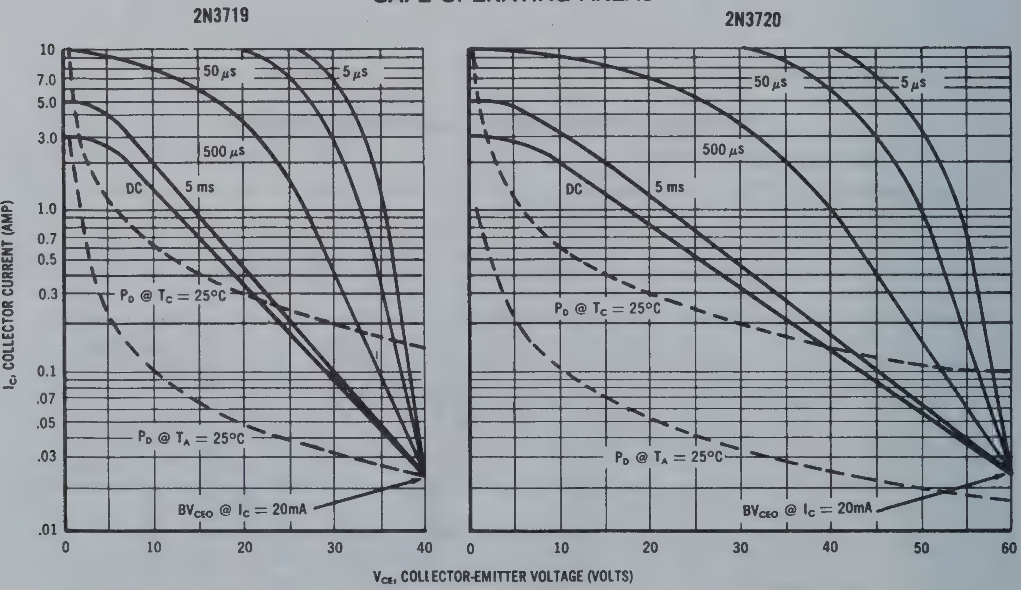
CASE 31
(TO-5)
Collector
connected to case

PNP silicon annular power transistors for high-speed, high-current switching in core, driver and Class C power applications.

MAXIMUM RATINGS

Rating	Symbol	2N3719	2N3720	Unit
Collector-Base Voltage	V_{CB}	40	60	Volts
Collector-Emitter Voltage	V_{CEO}	40	60	Volts
Emitter-Base Voltage	V_{EB}	4.0	4.0	Volts
Collector Current—Continuous Collector Current—Peak	I_C	3.0 10	3.0 10	Amp Amp
Base Current	I_B	0.5	0.5	Amp
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.72		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	6.0 34.3		Watts mW/°C
Operating Junction and Storage Temperature Range	T_J and T_{stg}	-65 to +200		°C

SAFE OPERATING AREAS

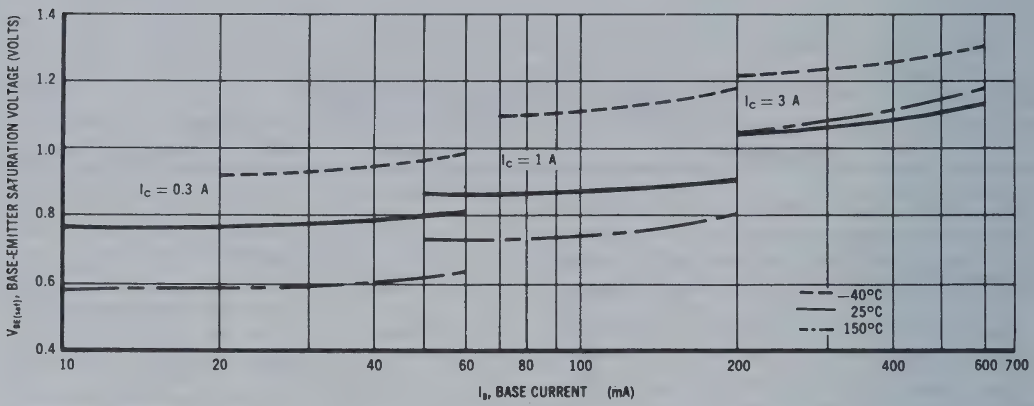


ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

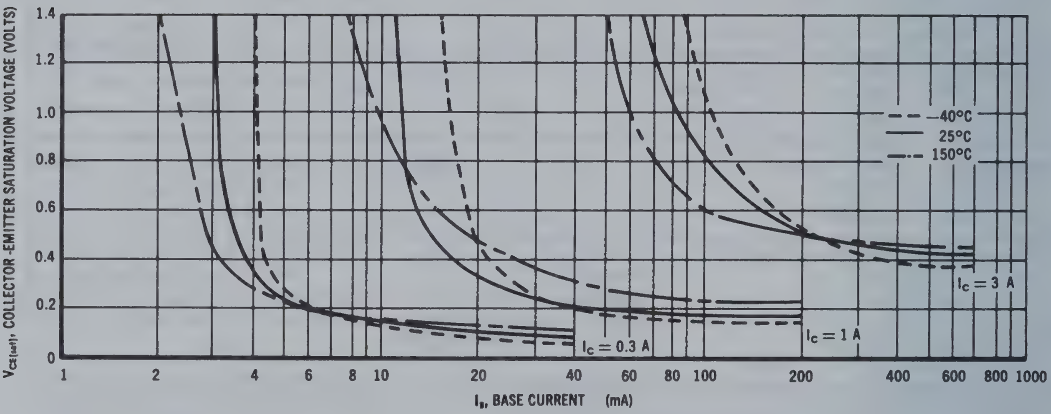
Characteristic		Symbol	Min	Max	Unit
Collector Leakage Current		I_{CEX}			μAdc
(V_{CE} = 40 Vdc, V_{BE} = 2 Vdc)	2N3719		—	10	
(V_{CE} = 60 Vdc, V_{BE} = 2 Vdc)	2N3720		—	10	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0, T_A = 25°C)	2N3719		—	0.010	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 150°C)	2N3719		—	1.0	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 25°C)	2N3720		—	0.010	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	2N3720		—	1.0	
Emitter-Base Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)		I_{EBO}	—	1.0	mAdc
DC Current Gain [1]		h_{FE}			—
(I_C = 500 mA, V_{CE} = 1.5 V, T_A = 25°C)			20	—	
(I_C = 1 A, V_{CE} = 1.5 V, T_A = 25°C)			25	180	
(I_C = 1 A, V_{CE} = 1.5 V, T_A = -40°C)			15	—	
Collector-Emitter Saturation Voltage [1]		$V_{CE(sat)}$			Volts
(I_C = 1 A, I_B = 100 mA, T_A = -40 to +100°C			—	0.75	
(I_C = 3 A, I_B = 300 mA, T_A = 25°C)			—	1.5	
Base-Emitter Saturation Voltage [1]		$V_{BE(sat)}$			Volts
(I_C = 1 A, I_B = 100 mA)			—	1.5	
(I_C = 3 A, I_B = 300 mA)			—	2.3	
Collector-Emitter Breakdown Voltage [1]		BV_{CEO}			Volts
(I_C = 20 mA, I_B = 0)	2N3719		40	—	
	2N3720		60	—	
Collector Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	120	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	1000	pF
Current-Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 500 mAdc, f = 30 MHz)		f_T	60	—	MHz
Turn-On Time (I_C = 1 Adc, I_{B1} = 100 mA)		t_{on}	—	100	ns
Turn-Off Time (I_C = 1 Adc, I_{B1} = I_{B2} = 100 mA)		t_{off}	—	400	ns

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

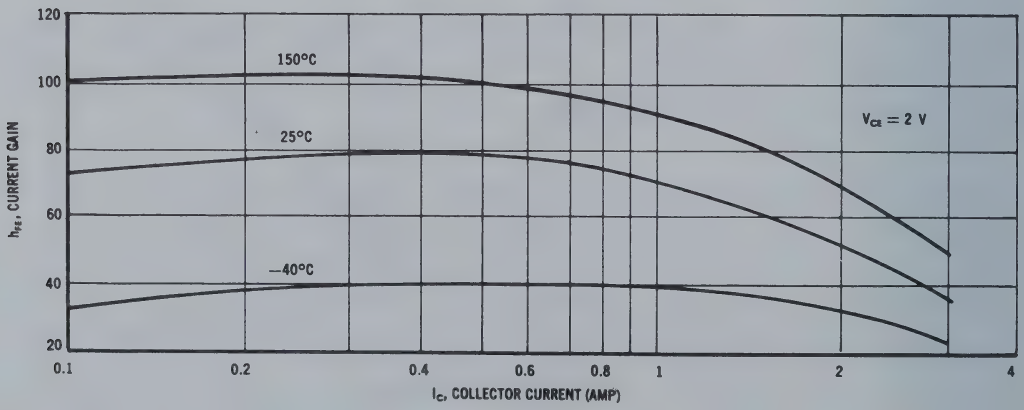
BASE EMITTER SATURATION VOLTAGE VARIATIONS



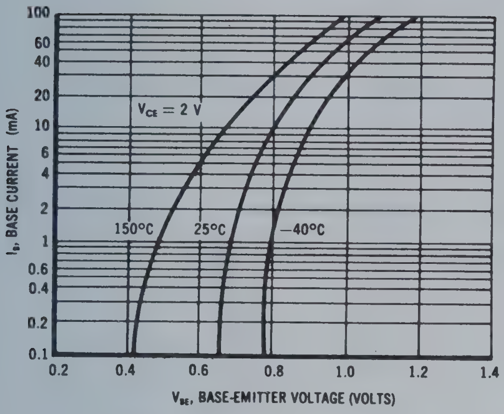
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



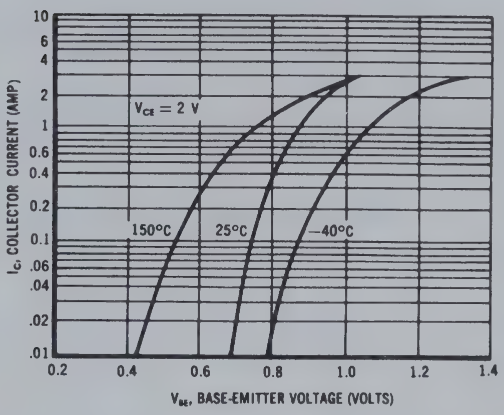
CURRENT GAIN VARIATIONS



BASE CURRENT — VOLTAGE VARIATIONS



COLLECTOR CURRENT vs BASE-EMITTER VOLTAGE



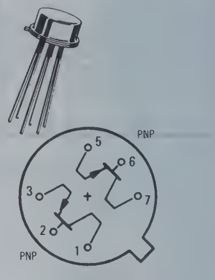
2N3726 (SILICON)
2N3727

DUAL PNP SILICON ANNULAR TRANSISTORS

. . . a matched pair of silicon bi-polar devices in a single package. Designed for general-purpose differential amplifier applications.

- Collector-Emitter Breakdown Voltage —
  BV_{CEO} = 45 Vdc (Min) @ I_C = 10 mAdc
- Low Noise Figure —
  NF = 4.0 dB (Max) @ I_C = 30 μAdc
- Low Base-Emitter Voltage Differential —
  $|V_{BE1} - V_{BE2}|$ = 2.5 mVdc (Max) (2N3727)

PNP SILICON AMPLIFIER TRANSISTORS


PNP
5
6
7
3
2
1
PNP

PINS 4 AND 8 OMITTED

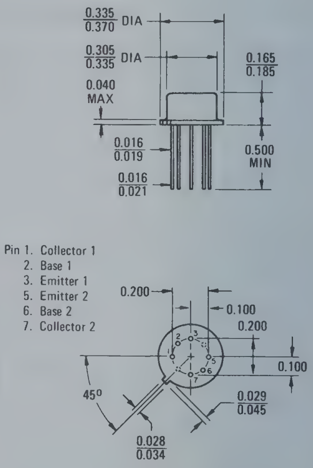
Pin Connections,
Bottom View

All Leads Electrically Isolated from Case

*MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector-Current	I_C	300		mAdc
Base Current	I_B	100		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.29	500 2.86	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.85 4.85	1.4 8.0	Watt mW/°C

*Indicates JEDEC Registered Data


0.335
0.370
DIA
0.305
0.335
DIA
0.165
0.185
0.040
MAX
0.016
0.019
0.500
MIN
0.016
0.021
0.200
0.100
0.200
0.100
45°
0.029
0.045
0.028
0.034
1
2
3
5
6
7

Pin 1. Collector 1
2. Base 1
3. Emitter 1
5. Emitter 2
6. Base 2
7. Collector 2

PINS 4 AND 8 OMITTED
All Leads Electrically Isolated from Case

CASE 654-04

2N3726, 2N3727 (continued)

***ELECTRICAL CHARACTERISTICS** (each side) ($T_A = 25^oC$ unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}	45	–	Vdc
Collector-Base Breakdown Voltage ($I_C = 0.01$ mAdc, $I_E = 0$)	BV_{CBO}	45	–	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.01$ mAdc, $I_C = 0$)	BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current	I_{CBO}			
($V_{CB} = 30$ Vdc, $I_E = 0$)		–	10	nAdc
($V_{CB} = 30$ Vdc, $I_E = 0$, $T_A = 150^oC$)		–	10	μAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	–	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			–
($I_C = 0.01$ mAdc, $V_{CE} = 5.0$ Vdc)		80	–	
($I_C = 0.1$ mAdc, $V_{CE} = 5.0$ Vdc)		120	–	
($I_C = 1.0$ mAdc, $V_{CE} = 5.0$ Vdc)		135	350	
($I_C = 50$ mAdc, $V_{CE} = 5.0$ Vdc) (1)		115	–	
Collector-Emitter Saturation Voltage (1) ($I_C = 50$ mAdc, $I_B = 2.5$ mAdc)	$V_{CE(sat)}$	–	0.25	Vdc
Base-Emitter Saturation Voltage (1) ($I_C = 50$ mAdc, $I_B = 2.5$ mAdc)	$V_{BE(sat)}$	–	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (2)	f_T			MHz
($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)		60	–	
($I_C = 50$ mAdc, $V_{CE} = 20$ Vdc, f = 100 MHz)		200	600	
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 1.0 MHz)	C_{ob}	–	8.0	pF
Input Capacitance ($V_{EB} = 0.5$ Vdc, $I_C = 0$, f = 1.0 MHz)	C_{ib}	–	30	pF
Input Impedance ($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{ie}	–	11.5	k ohm
Voltage Feedback Ratio ($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{re}	–	15	$X\ 10^{-4}$
Small-Signal Current Gain ($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	135	420	–
Output Admittance ($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{oe}	–	80	μmhos
Noise Figure ($I_C = 30$ μAdc, $V_{CE} = 5.0$ Vdc, $R_S = 10$ k ohms, f = 1.0 kHz, B.W. = 200 Hz)	NF	–	4.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio (3) ($I_C = 0.1$ mAdc to 1.0 mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE1}/h_{FE2}	0.9	1.0	–
Base-Emitter Voltage Differential	$\lvert V_{BE1}-V_{BE2}\rvert$			mVdc
($I_C = 0.1$ mAdc to 1.0 mAdc, $V_{CE} = 5.0$ Vdc) 2N3726		–	5.0	
2N3727		–	2.5	
Base-Emitter Voltage Differential Change	$\Delta(V_{BE1}-V_{BE2})$			mVdc
($I_C = 0.1$ mAdc to 1.0 mAdc, $V_{CE} = 5.0$ Vdc, 2N3726		–	1.6	
$T_A = -55^oC$ to $+25^oC$) 2N3727		–	0.8	
($I_C = 0.1$ mAdc to 1.0 mAdc, $V_{CE} = 5.0$ Vdc, 2N3726		–	2.0	
$T_A = +25^oC$ to $+125^oC$) 2N3727		–	1.0	

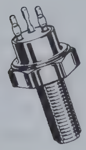
*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Length = 300 μs, Duty Cycle = 1.0%.

(2) f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

(3) For purposes of this ratio, the lowest h_{FE} reading is taken as h_{FE1}.

2N3733 (SILICON)



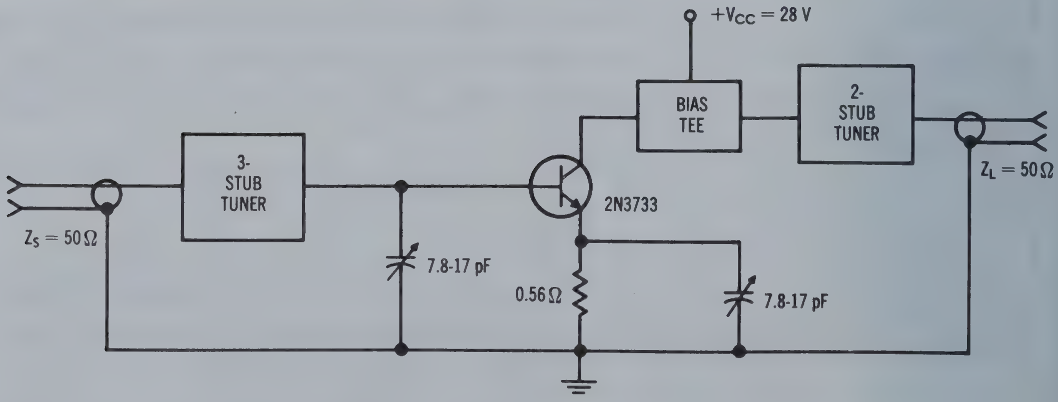
CASE 36
(TO-60)
stud isolated from case

NPN silicon transistor designed for amplifier, frequency multiplier, and oscillator applications.

MAXIMUM RATINGS ($T_A = 25^oC$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage ($V_{EB(off)} = 1.5$ Vdc)	V_{CEV}	65	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	3.0	Amps
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	23 0.13	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — 400-MHz TEST CIRCUIT



+V_{CC} = 28 V
BIAS TEE
2-STUB TUNER
3-STUB TUNER
$Z_L = 50\Omega$
$Z_S = 50\Omega$
2N3733
7.8-17 pF
0.56Ω
7.8-17 pF

ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

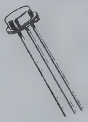
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 0 to 200 mAdc, I_B = 0)	BV_{CEO}	40	-	-	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 0 to 200 mAdc, $V_{EB(off)}$ = 1.5 Vdc)	BV_{CEV}	65	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.5 mAdc, I_E = 0)	BV_{CBO}	65	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.25 mAdc, I_C = 0)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	-	0.25	mAdc
ON CHARACTERISTICS					
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 100 mAdc)	$V_{CE(sat)}$	-	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 150 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	f_T	-	400	-	MHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0)	C_{ob}	-	-	20	pF
Collector-Case Capacitance	C_s	-	-	6.0	pF
Base-Spreading Resistance (I_C = 250 mAdc, V_{CE} = 28 Vdc, f = 200 MHz)	r_{bb}'	-	6.5	-	Ohms

FUNCTIONAL TEST

Power Output	V_{CE} = 28 Vdc, P_{in} = 4 W, f = 260 MHz	P_{out}	-	14.5	-	Watts
Efficiency		η	-	60	-	%
Power Output	V_{CE} = 28 Vdc, P_{in} = 4 W, f = 400 MHz (Figure 1)	P_{out}	10	-	-	Watts
Efficiency		η	45	-	-	%

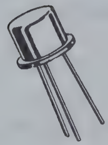
(1) Pulsed through a 25 mH inductor; duty cycle = 50%

2N3734 (SILICON)
2N3735
2N3736
2N3737



CASE 26
(TO-46)

2N3736
2N3737



CASE 79
(TO-39)

2N3734
2N3735

Collector connected to case

Medium current NPN silicon annular transistors designed for high-speed switching and driver applications.

MAXIMUM RATINGS

(T_A = 25°C unless otherwise noted)

Rating	Symbol	2N3734 2N3736	2N3735 2N3737	Unit
Collector-Base Voltage	V_{CB}	50	75	Vdc
Collector-Emitter Voltage	V_{CEO}	30	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.5		Adc
		TO-39 2N3734 2N3735	TO-46 2N3736 2N3737	
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	1.0 5.71	0.5 2.86	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	4.0 22.8	2.0 11.4	Watts mW/°C
Thermal Resistance Junction to Ambient Junction to Case	 θ_{JA} θ_{JC}	 0.175 0.044	 0.35 0.088	°C/mW
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

2N3734, 2N3735, 2N3736, 2N3737 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

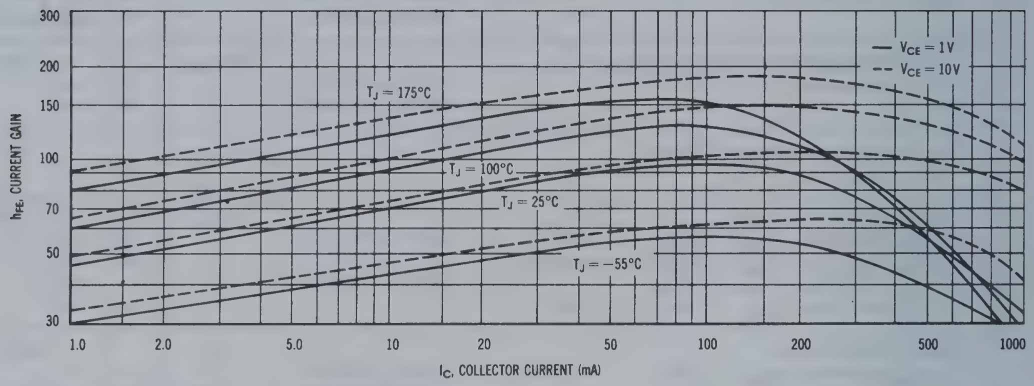
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N3734, 2N3736	BV_{CBO}	50	—	Vdc
	2N3735, 2N3737		75	—	
Collector-Emitter Breakdown Voltage $^{(1)}$ (I_C = 10 mAdc, I_B = 0)	2N3734, 2N3736	BV_{CEO}	30	—	Vdc
	2N3735, 2N3737		50	—	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 25 Vdc, V_{EB} = 2 Vdc)	2N3734, 2N3736	I_{CEX}	—	0.20	μAdc
(V_{CE} = 25 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)			—	20	
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc)	2N3735, 2N3737		—	0.20	
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)			—	20	
Base Cutoff Current (V_{CE} = 25 Vdc, V_{EB} = 2 Vdc)	2N3734, 2N3736	I_{BL}	—	0.3	μAdc
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc)	2N3735, 2N3737		—	0.3	
ON CHARACTERISTICS					
DC Current Gain $^{(1)}$ (I_C = 10 mAdc, V_{CE} = 1 Vdc)		h_{FE}	35	—	—
(I_C = 150 mAdc, V_{CE} = 1 Vdc)			40	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)			35	—	
(I_C = 1 Adc, V_{CE} = 1.5 Vdc)	2N3734, 2N3736		30	120	
	2N3735, 2N3737		20	80	
(I_C = 1.5 Adc, V_{CE} = 5 Vdc)	2N3734, 2N3736		30	—	
	2N3735, 2N3737		20	—	
Collector Saturation Voltage $^{(1)}$ (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{CE(sat)}$	—	0.2	Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	0.3	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	0.5	
(I_C = 1 Adc, I_B = 100 mAdc)			—	0.9	
Base-Emitter Saturation Voltage $^{(1)}$ (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	—	0.8	Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.2	
(I_C = 1 Adc, I_B = 100 mAdc)			0.9	1.4	
DYNAMIC CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	9.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
High-Frequency Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		h_{fe}	2.5	—	—
Delay Time	(V_{CC} = 30 V, $V_{BE(off)}$ = 2 V, I_C = 1 Amp, I_{B1} = 100 mA)	t_d	—	8.0	ns
Rise Time		t_r	—	40	ns
Storage Time	(V_{CC} = 30 V, I_C = 1 Amp, I_{B1} = $-I_{B2}$ = 100 mA)	t_s	—	30	ns
Fall Time		t_f	—	30	ns
Total Control Charge (I_C = 1 Amp, I_B = 100 mA, V_{CC} = 30 V)		Q_T	—	10	nC

(1) Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

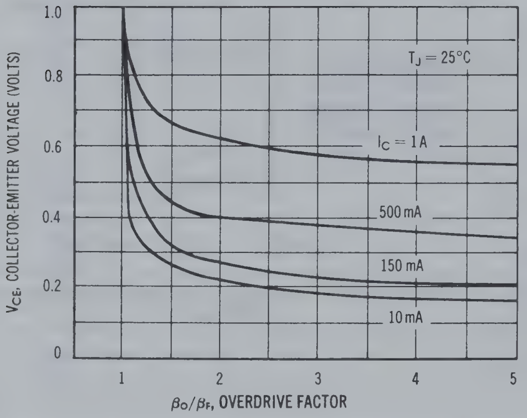
"ON" CONDITION CHARACTERISTICS

FIGURE 1

DC CURRENT GAIN



COLLECTOR SATURATION REGION

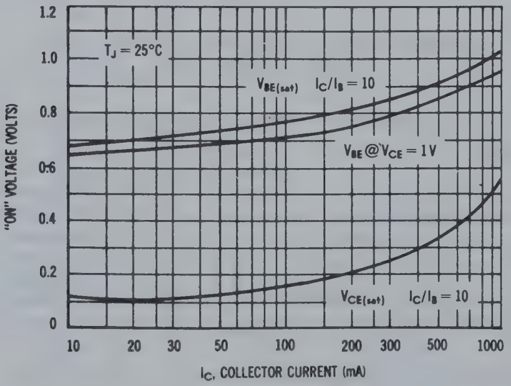


This graph shows the effect of base current on collector current. β_O (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3734, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 500 mA.

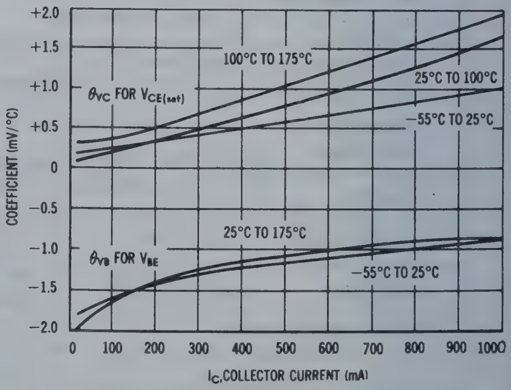
Observe that at $I_C = 500$ mA an overdrive factor of at least 2.0 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is typically 54 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design). ∴

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\text{ Volt}}{I_C/I_{BF}} \quad \therefore \quad 2 = \frac{54}{500\text{ mA}/I_{BF}} \quad \therefore \quad I_{BF} \approx 18.5\text{ mA typ}$$

"ON" VOLTAGES

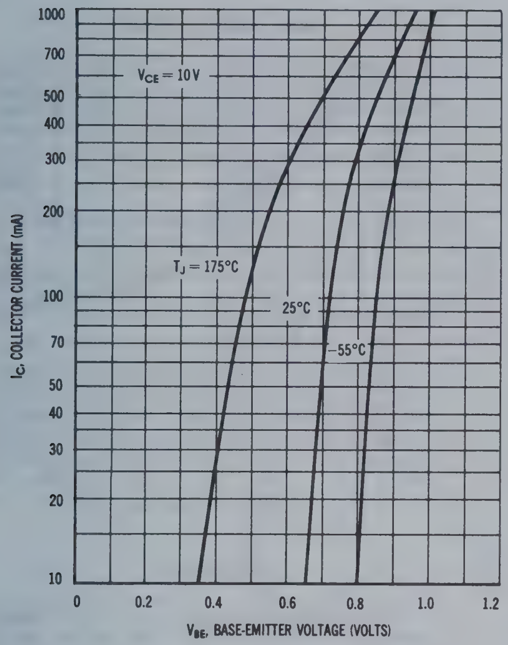


TEMPERATURE COEFFICIENTS

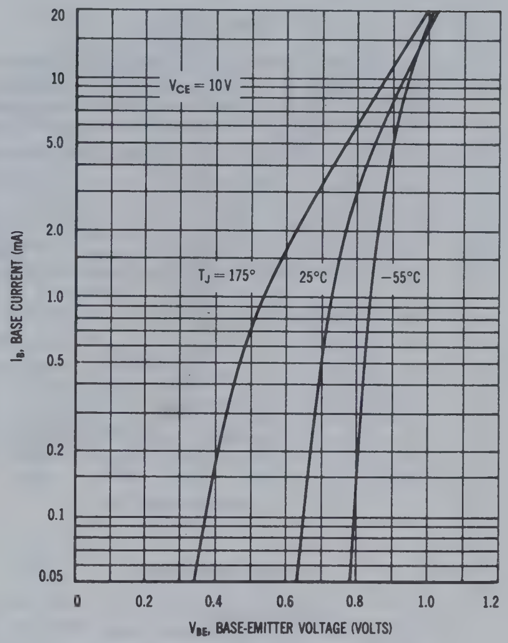


LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

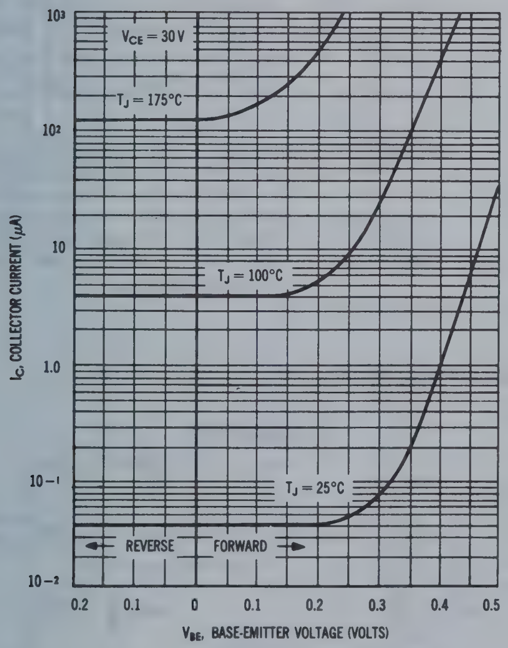


INPUT ADMITTANCE

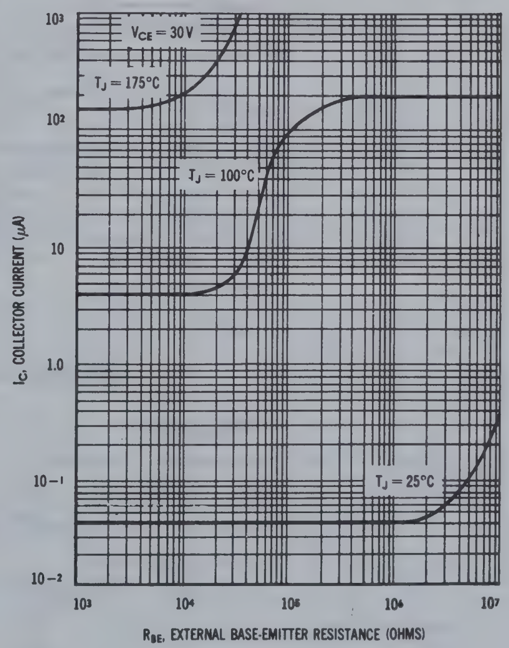


"OFF" CONDITION CHARACTERISTICS

TRANSCONDUCTANCE



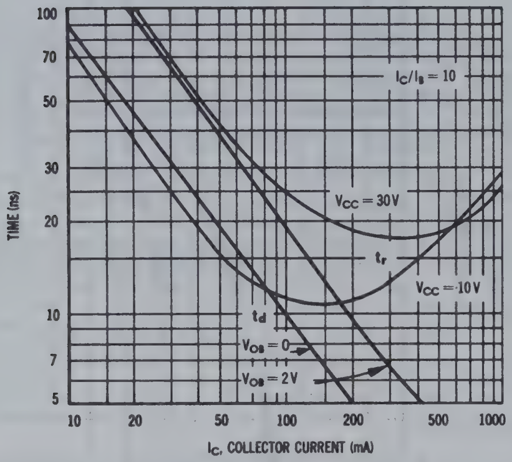
EFFECT OF BASE-EMITTER RESISTANCE



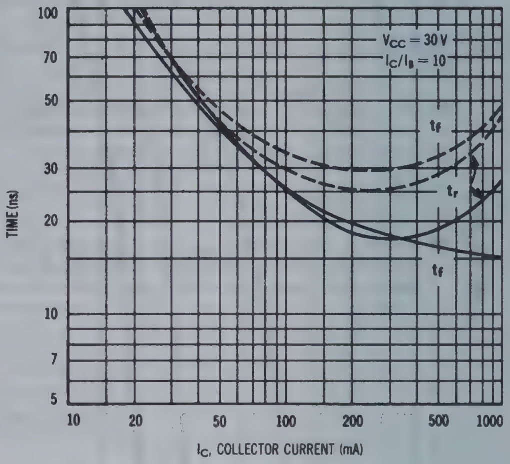
SWITCHING CHARACTERISTICS

— $T_J = 25°C$ -- $T_J = 150°C$

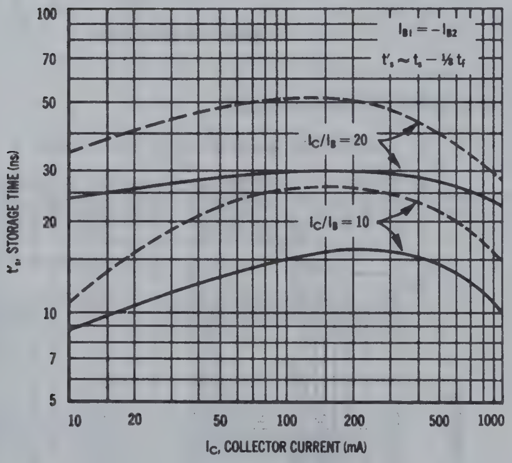
TURN-ON TIME



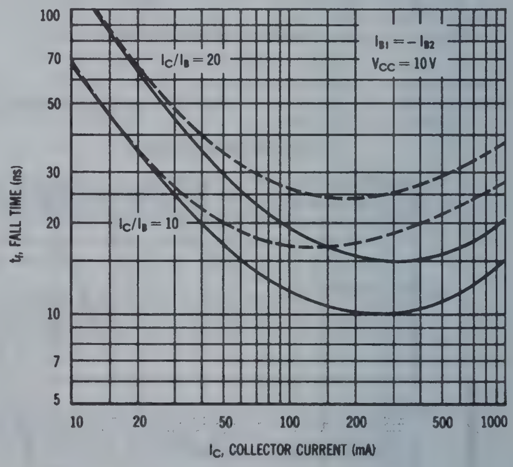
RISE AND FALL TIMES



STORAGE TIME

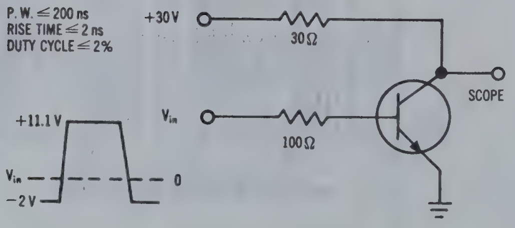


FALL TIME

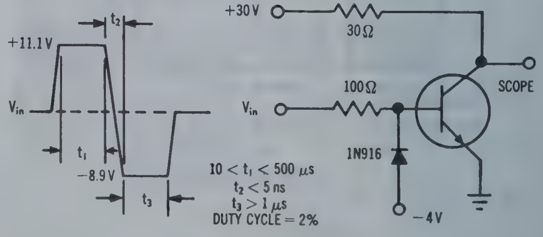


SWITCHING TIME EQUIVALENT TEST CIRCUITS

TURN-ON TIME

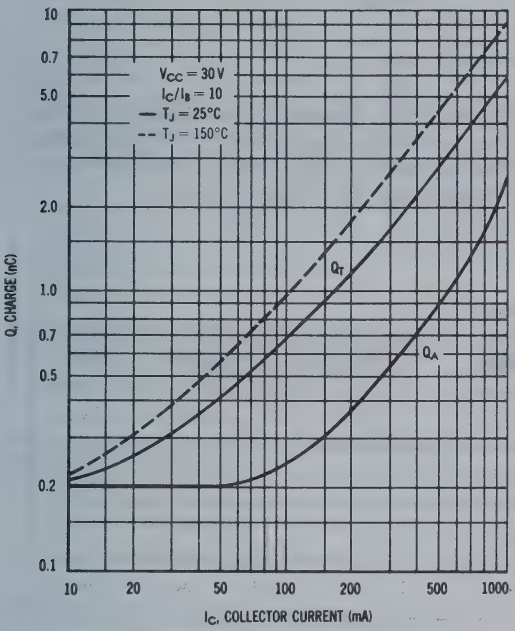

P. W. ≤ 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 2%
+30 V
30 Ω
SCOPE
V_{in}
100 Ω
+11.1 V
V_{in}
0
−2 V

TURN-OFF TIME

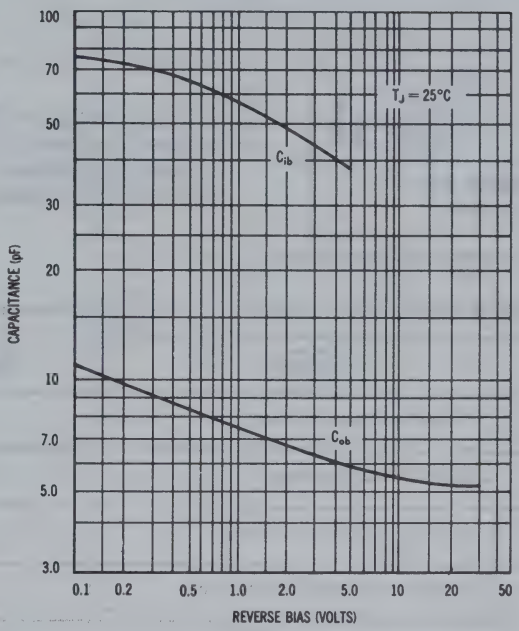

t_2
+11.1 V
V_{in}
t_1
−8.9 V
t_3
+30 V
30 Ω
100 Ω
SCOPE
V_{in}
1N916
−4 V

$10 < t_1 < 500\ \mu s$
$t_2 < 5$ ns
$t_3 > 1\ \mu s$
DUTY CYCLE = 2%

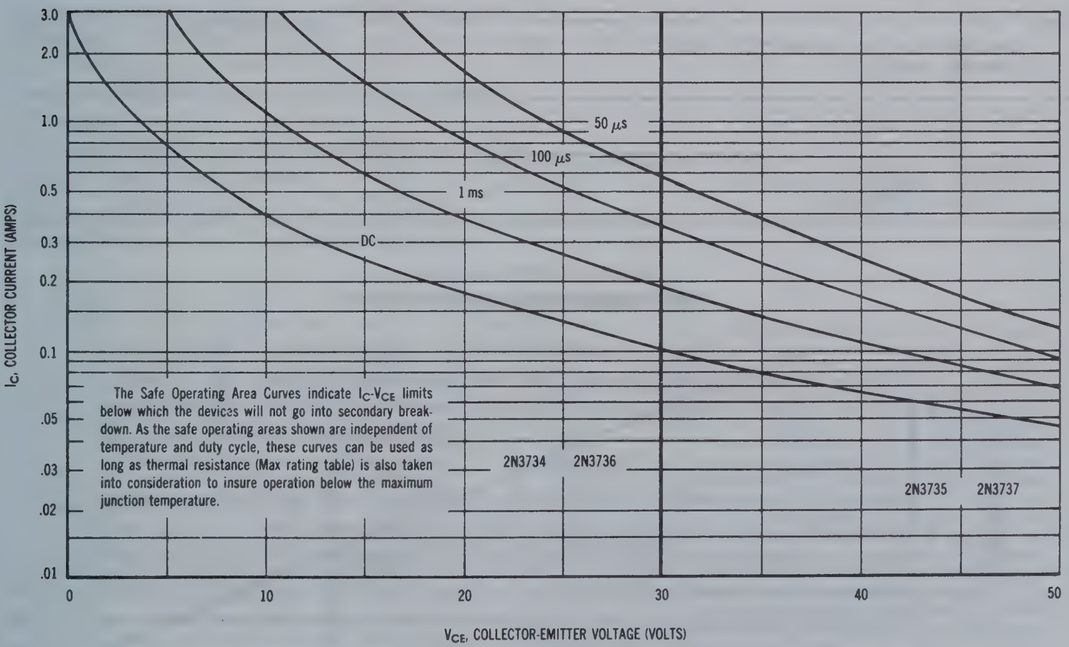
CHARGE DATA



CAPACITANCE

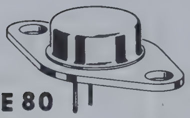


ACTIVE REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as thermal resistance (Max rating table) is also taken into consideration to insure operation below the maximum junction temperature.

2N3738 (SILICON)
2N3739



CASE 80
(TO-66)

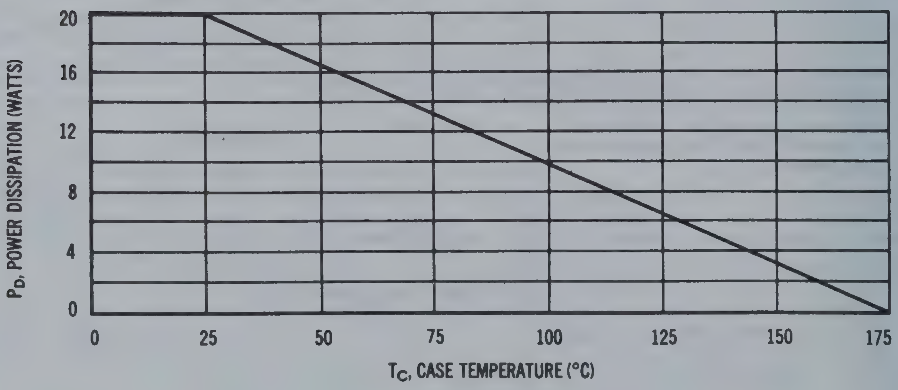
Collector connected to case

High-voltage NPN silicon power transistors, designed for use in line operated equipment such as audio output amplifiers; low-current, high-voltage converters; and AC line relays, featuring excellent dc gain.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N3738	2N3739	Unit
Collector-Base Voltage	V_{CB}	250	325	Vdc
Emitter-Base Voltage	V_{EB}	6.0	6.0	Vdc
Collector-Emitter Voltage	V_{CEO}	225	300	Vdc
Collector Current (Continuous)	I_C	3.0		Adc
Collector Current (Peak)	I_C	3.0		Amp
Base Current	I_B	1.0		Amp
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	20 0.133		Watts W/°C
Thermal Resistance	θ_{JC}	7.5		°C/W
Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +175		°C

POWER-TEMPERATURE DERATING CURVE



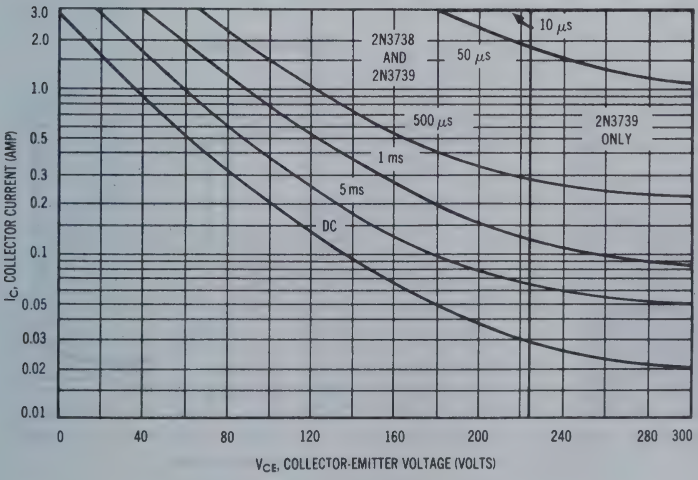
2N3738, 2N3739 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1)		$V_{CEO(sus)}$			Vdc
(I_C = 5 mAdc, I_B = 0)	2N3738		225	—	
	2N3739		300	—	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 6 Vdc)			—	0.1	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 250 Vdc, V_{BE} = 1.5 Vdc)	2N3738		—	0.5	
(V_{CE} = 300 Vdc, V_{BE} = 1.5 Vdc)	2N3739		—	0.5	
(V_{CE} = 125 Vdc, V_{BE} = 1.5 Vdc, T_C = 100°C)	2N3738		—	1.0	
(V_{CE} = 200 Vdc, V_{BE} = 1.5 Vdc, T_C = 100°C)	2N3739		—	1.0	
Collector-Emitter Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 125 Vdc, I_B = 0)	2N3738		—	0.25	
(V_{CE} = 200 Vdc, I_B = 0)	2N3739		—	0.25	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 250 Vdc, I_E = 0)	2N3738		—	0.1	
(V_{CB} = 325 Vdc, I_E = 0)	2N3739		—	0.1	
ON CHARACTERISTICS					
DC Current Gain (1)		h_{FE}			—
(I_C = 50 mAdc, V_{CE} = 10 Vdc)			30	—	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)			40	200	
(I_C = 250 mAdc, V_{CE} = 10 Vdc)			25	—	
Collector-Emitter Saturation Voltage (1)		$V_{CE(sat)}$			Vdc
(I_C = 250 mAdc, I_B = 25 mAdc)			—	2.5	
Base-Emitter Voltage (1)		V_{BE}			Vdc
(I_C = 100 mAdc, V_{CE} = 10 Vdc)			—	1.0	
TRANSIENT CHARACTERISTICS					
Current-Gain—Bandwidth Product		f_T			MHz
(I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)			10	—	
Common Base Output Capacitance		C_{ob}			pF
(V_{CB} = 100 Vdc, I_C = 0, f = 100 kHz)			—	20	
Small Signal Current Gain		h_{fe}			—
(I_C = 100 mAdc, V_{CE} = 20 Vdc, f = 1 kHz)			35	—	

(1)PULSE TEST: PW ≤ 300 µs, Duty Cycle ≤ 2%

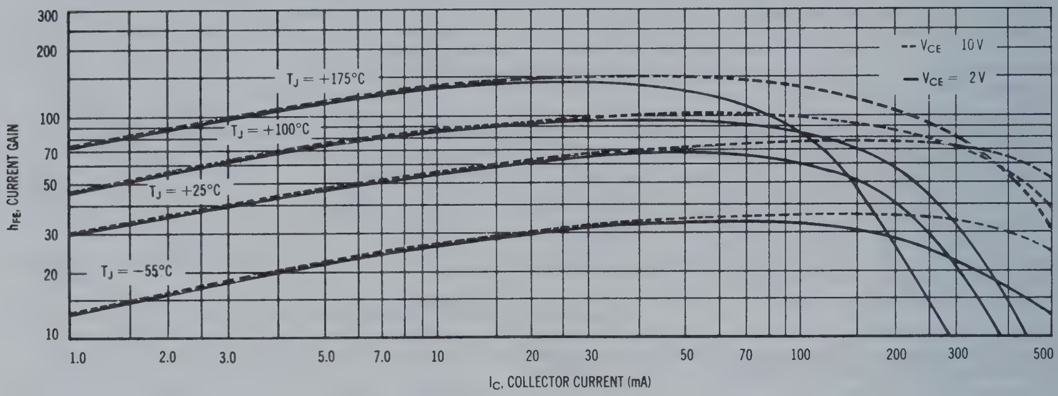
ACTIVE REGION SAFE AREAS



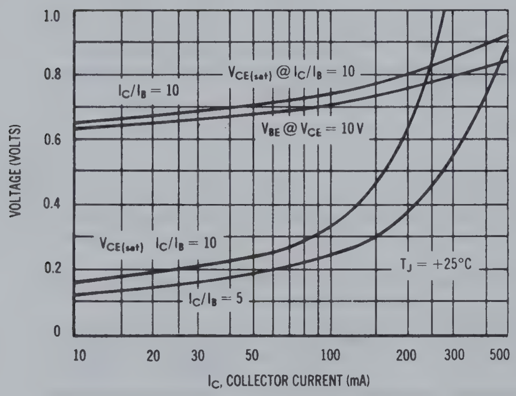
The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CEO} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CEO} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N3738, 2N3739 (continued)

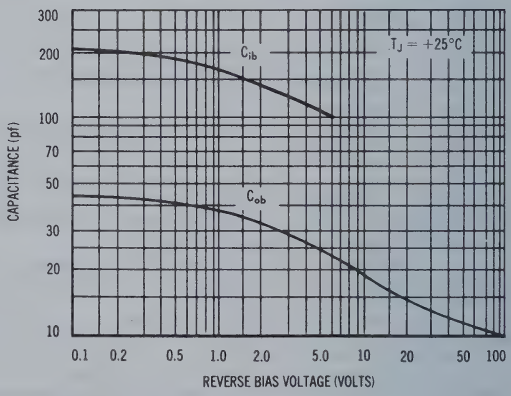
CURRENT GAIN



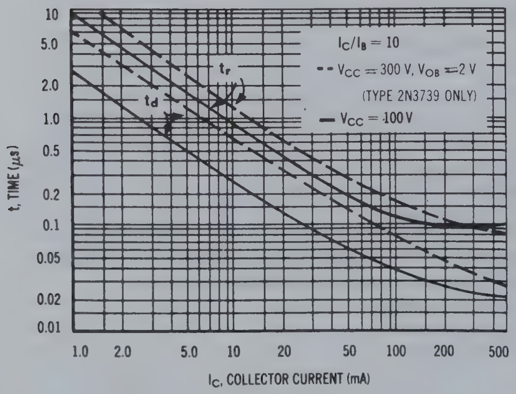
"ON" VOLTAGES



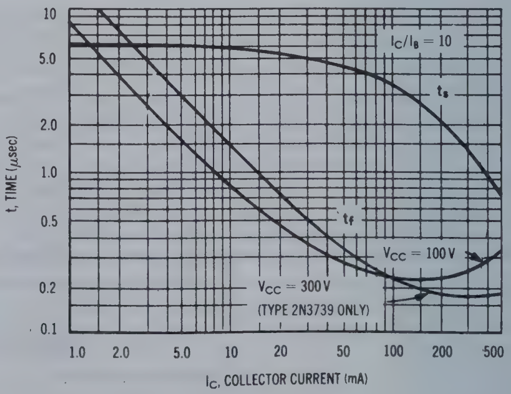
CAPACITANCE



TURN-ON TIME

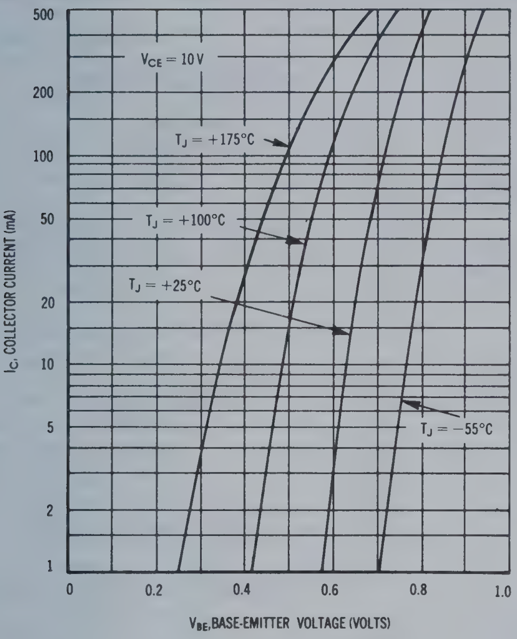


TURN-OFF TIME

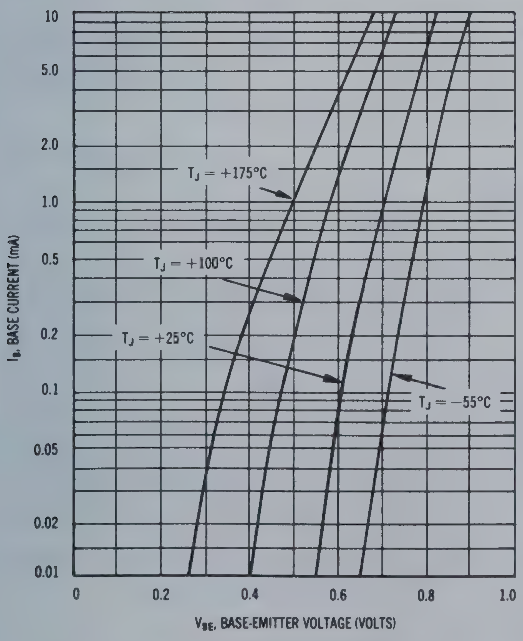


LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

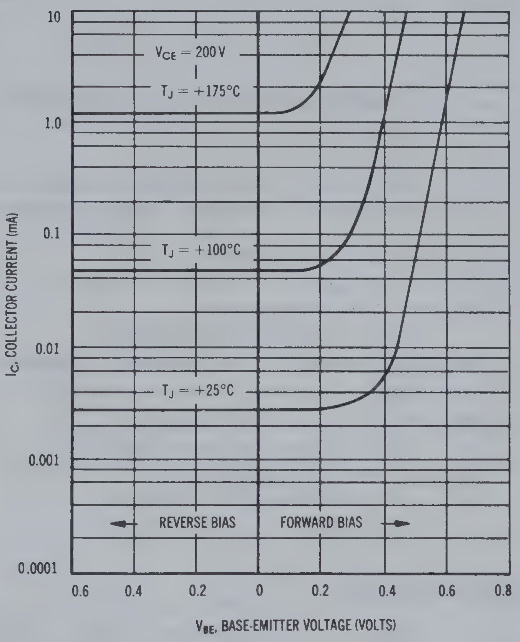


INPUT ADMITTANCE

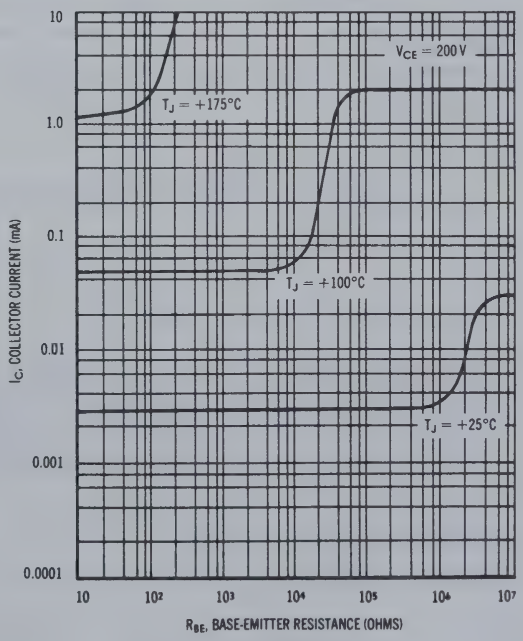


CUT-OFF CHARACTERISTICS

TRANSCONDUCTANCE



EFFECT OF BASE-EMITTER RESISTANCE



2N3740, A (SILICON)
2N3741, A

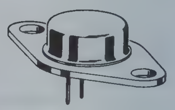
MEDIUM-POWER PNP TRANSISTORS

. . . ideal for use as drivers, switches and direct replacement of germanium medium-power devices. These devices feature:

- Low Saturation Voltage —
  $V_{CE(sat)} = 0.6$ Vdc @ $I_C = 1.0$ Amp
- High Gain Characteristics —
  $h_{FE} = 30–100$ @ $I_C = 250$ mAdc
- Direct Substitution for Germanium Equivalents
- Excellent Safe Area Limits (See Figure 2)
- Low Collector Cutoff Current —
  100 nA (Max) 2N3740A, 2N3741A
- Complementary to NPN 2N3766
  (2N3740) and 2N3767 (2N3741)

POWER TRANSISTORS

PNP SILICON
60–80 VOLTS
25 WATTS

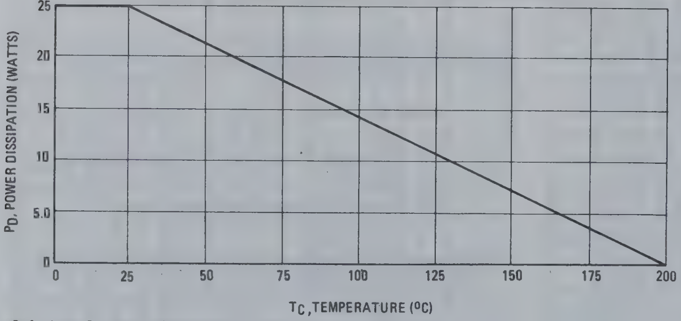


*MAXIMUM RATINGS

Rating	Symbol	2N3740 2N3740A	2N3741 2N3741A	Unit
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0	7.0	Vdc
Collector-Base Voltage	V_{CB}	60	80	vdc
Collector Current — Continuous — Peak (Note 1)	I_C	4.0 10		Adc
Base Current	I_B	2.0		Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	25 0.143		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

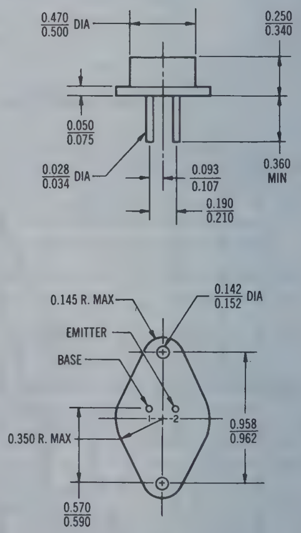
Note 1: See Figure 2

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 2.
Both limits are applicable and must be observed.

*Indicates JEDEC Registered Data.


0.470
0.500 DIA
0.250
0.340
0.050
0.075
0.028
0.034 DIA
0.093
0.107
0.190
0.210
0.360
MIN
0.145 R. MAX
0.142
0.152 DIA
EMITTER
BASE
1
2
0.350 R. MAX
0.958
0.962
0.570
0.590

CASE 80
(TO-66)

COLLECTOR CONNECTED TO CASE

2N3740,A, 2N3741,A (continued)

*ELECTRICAL CHARACTERISTICS ($T_C = 25^{\circ}C$ unless otherwise noted)

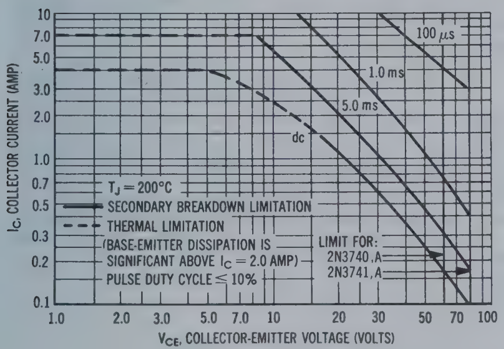
Characteristic		Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage ①		2	$V_{CEO(sus)}$ ①			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3740, 2N3740A			60	–	
	2N3741, 2N3741A			80	–	
Emitter Base Cutoff Current		–	I_{EBO}			
(V_{EB} = 7.0 Vdc)	2N3740, 2N3741			–	0.5	mAdc
	2N3740A, 2N3741A				100	nAdc
Collector Cutoff Current		5, 6②	I_{CEX}			
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N3740			–	100	µAdc
	2N3740A			–	100	nAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N3741			–	100	µAdc
	2N3741A			–	100	nAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N3740			–	1.0	mAdc
	2N3740A			–	0.5	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N3741			–	1.0	mAdc
	2N3741A			–	0.5	
Collector-Emitter Cutoff Current		5, 6②	I_{CEO}			
(V_{CE} = 40 Vdc, I_B = 0)	2N3740			–	1.0	mAdc
	2N3740A			–	1.0	µAdc
(V_{CE} = 60 Vdc, I_B = 0)	2N3741			–	1.0	mAdc
	2N3741A			–	1.0	µAdc
Collector Base Cutoff Current		–	I_{CBO}			
(V_{CB} = 60 Vdc, I_E = 0)	2N3740			–	100	µAdc
	2N3740A			–	100	nAdc
(V_{CB} = 80 Vdc, I_E = 0)	2N3741			–	100	µAdc
	2N3741A			–	100	nAdc
ON CHARACTERISTICS						
DC Current Gain		7	h_{FE} ①			–
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)				40	–	
(I_C = 250 mAdc, V_{CE} = 1.0 Vdc)				30	100	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)				20	–	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)				10	–	
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 125 mAdc)		8, 9, 10	$V_{CE(sat)}$ ①	–	0.6	Vdc
Base-Emitter Voltage (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)		3, 4, 9, 10	V_{BE} ①	–	1.0	Vdc
TRANSIENT CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)		–	f_T	4.0	–	MHz
Common Base Output Capacitance (V_{CB} = 10 Vdc, I_C = 0, f = 100 kHz)		14	C_{ob}	–	100	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		–	h_{fe}	25	–	–

*Indicates JEDEC Registered Data.

① Pulse Test: Pulse Width ≤300 µs, Duty Cycle ≤2.0%.

② Figures 5 and 6 apply to 2N3740 and 2N3741 only.

FIGURE 2 – ACTIVE REGION SAFE OPERATING AREA



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

LARGE SIGNAL CHARACTERISTICS

FIGURE 3 – TRANSCONDUCTANCE

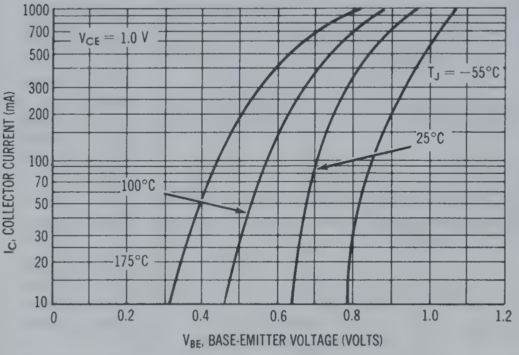
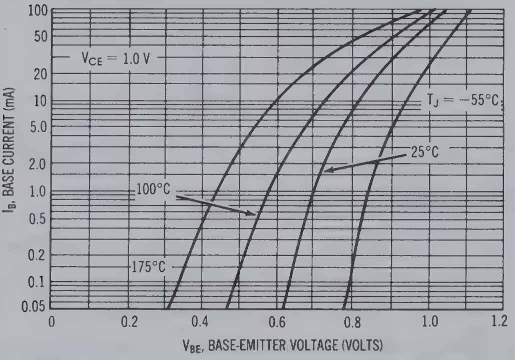


FIGURE 4 – INPUT ADMITTANCE



"OFF" REGION CHARACTERISTICS

FIGURE 5 – TRANSCONDUCTANCE

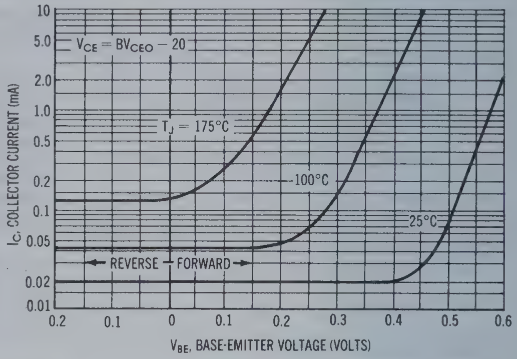
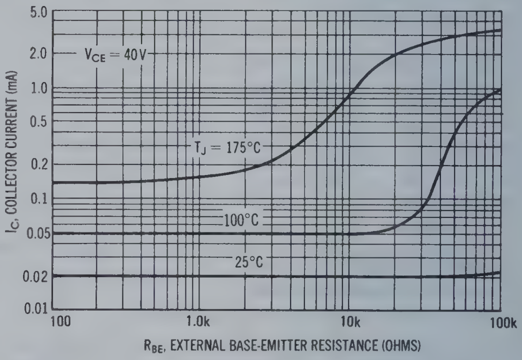


FIGURE 6 – EFFECTS OF BASE-EMITTER RESISTANCE



② Figures 5 and 6 apply to 2N3740 and 2N3741.

FIGURE 7 – THERMAL RESPONSE

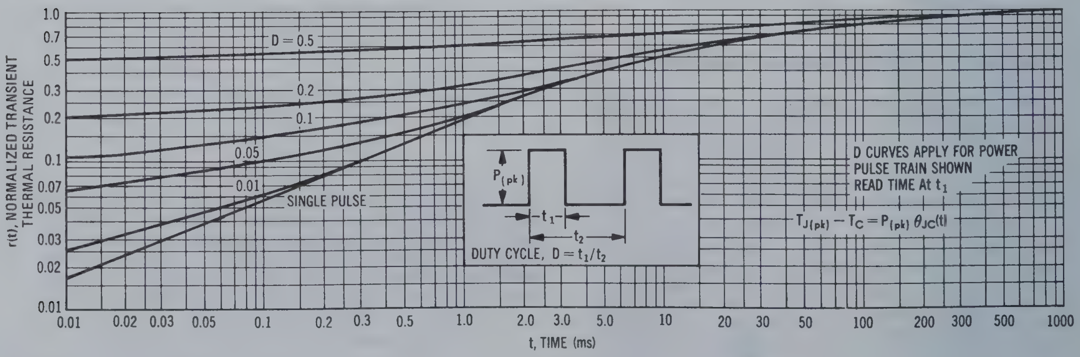
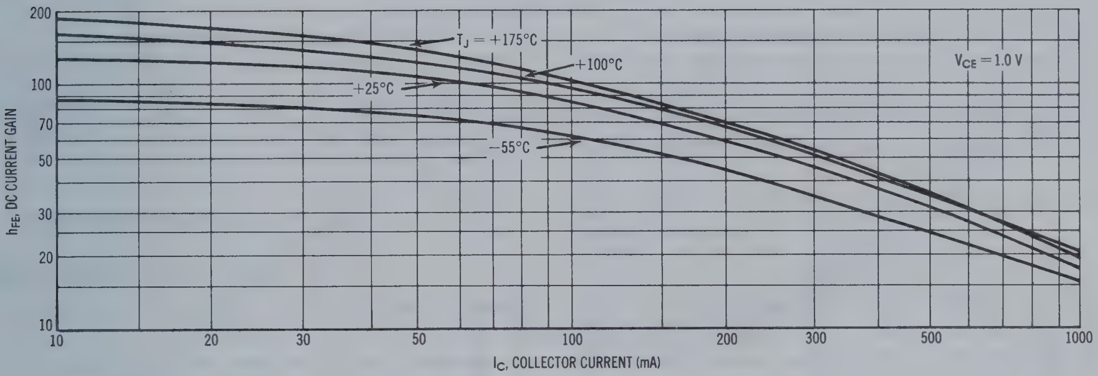


FIGURE 8 – CURRENT GAIN



SATURATION REGION CHARACTERISTICS

FIGURE 9 – COLLECTOR SATURATION REGION

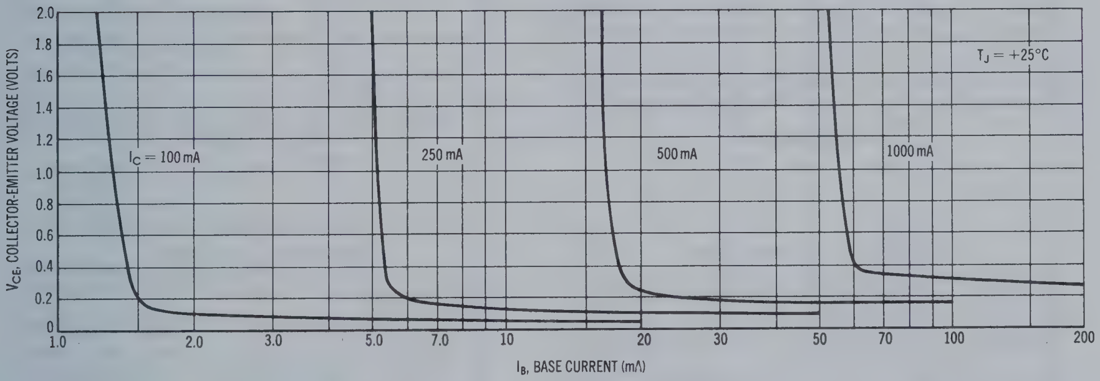


FIGURE 10 – "ON" VOLTAGES

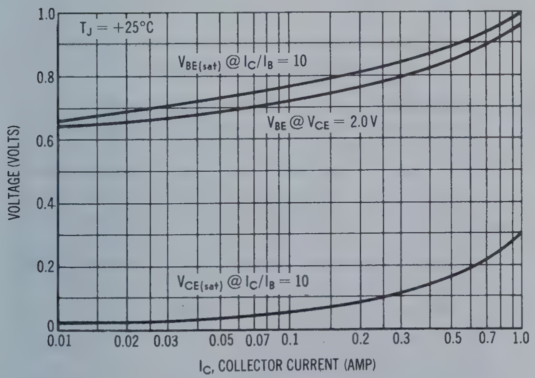
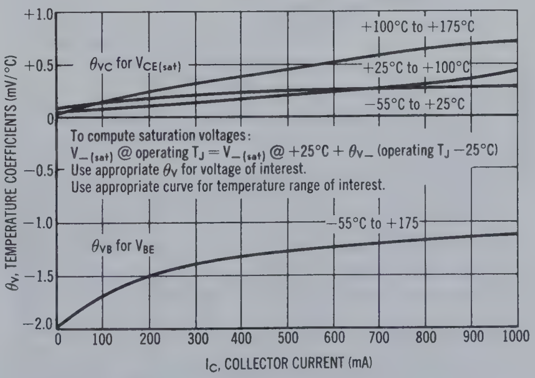


FIGURE 11 – TEMPERATURE COEFFICIENTS



To compute saturation voltages:
$V_{-(sat)}$ @ operating $T_J = V_{-(sat)}$ @ +25°C + θ_{V-} (operating T_J −25°C)
Use appropriate θ_V for voltage of interest.
Use appropriate curve for temperature range of interest.

FIGURE 12 – TURN-ON TIME

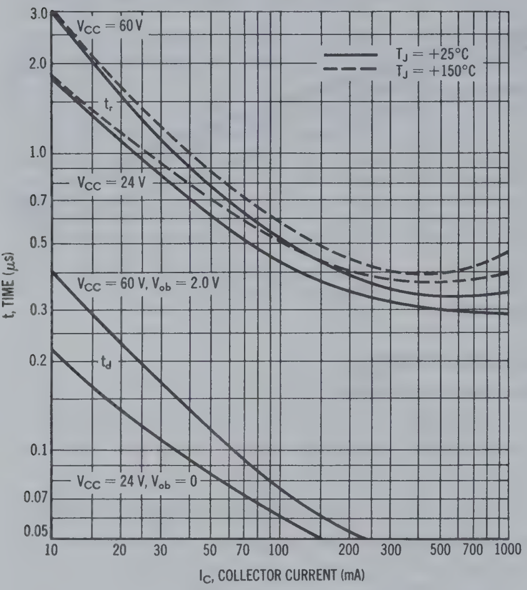


FIGURE 13 – CAPACITANCE

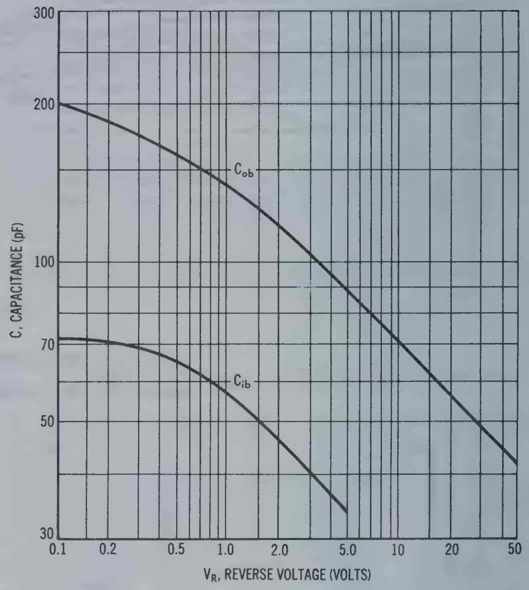


FIGURE 14 – STORAGE TIME

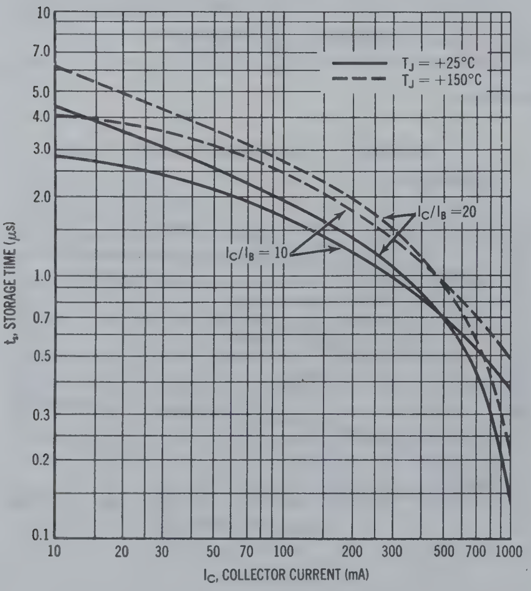
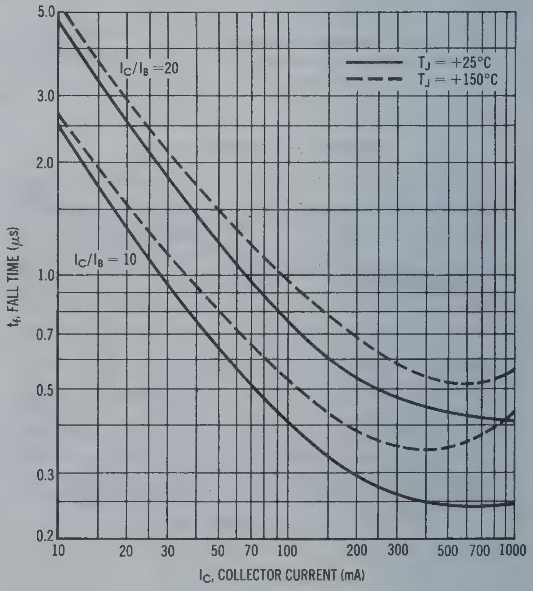


FIGURE 15 – FALL TIME



2N3742 (SILICON)

CASE 31
(TO-5)

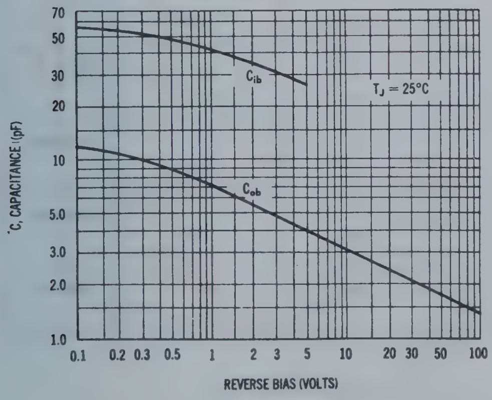
NPN silicon annular transistor for high-voltage amplifier applications from DC to VHF.

Collector connected to case

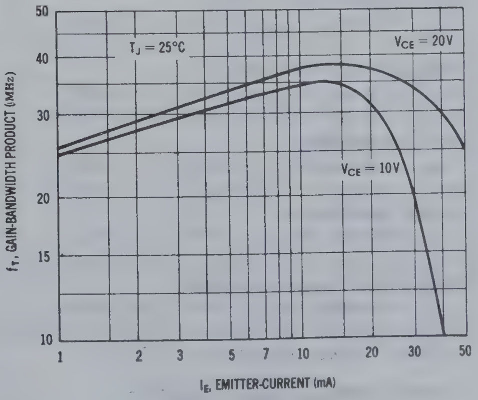
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	300	Vdc
Collector-Emitter Voltage	V_{CEO}	300	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derating Factor Above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derating Factor Above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

JUNCTION CAPACITANCE



GAIN-BANDWIDTH PRODUCT



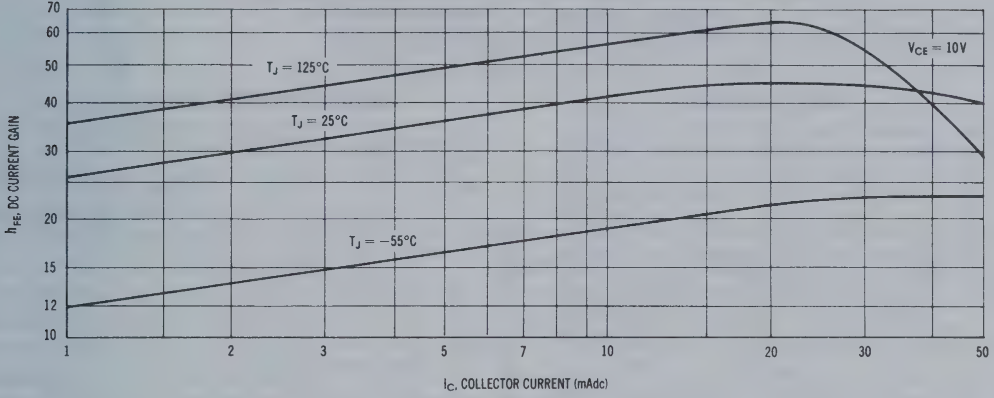
ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	300	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO}{}^*$	300	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100μAdc, I_C = 0)	BV_{EBO}	7.0	—	Vdc
Collector Saturation Voltage ** (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}{}^{**}$	—	1.0	Vdc
(I_C = 30 mAdc, I_B = 3 mAdc)		—	5.0	
Base-Emitter Saturation Voltage ** (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}{}^{**}$	—	1.0	Vdc
(I_C = 30 mAdc, I_B = 3 mAdc)		—	1.2	
DC Current Gain ** (I_C = 3 mAdc, V_{CE} = 10 Vdc)	$h_{FE}{}^{**}$	10	—	—
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		15	—	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)		20	200	
(I_C = 50 mAdc, V_{CE} = 20 Vdc)		20	—	
Collector Cutoff Current (V_{CB} = 200 Vdc, I_E = 0)	I_{CBO}	—	0.2	μAdc
(V_{CB} = 200 Vdc, I_E = 0, T_A = 100°C)		—	20	
Emitter Cutoff Current V_{EB} = 6 Vdc, I_C = 0)	I_{EBO}	—	0.2	μAdc
Small Signal Current Gain (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 20 MHz)	$\|h_{fe}\|$	1.5	—	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	80	pF
Small Signal Current Gain (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{fe}	20	200	—
Voltage Feedback Ratio (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{re}	—	1.0	$X10^{-4}$
Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{ie}	—	1.0	Kohms
Output Admittance (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{oe}	5.0	50	μmhos
Real Part of Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 5 MHz)	$Re(h_{ie})$	—	40	ohms

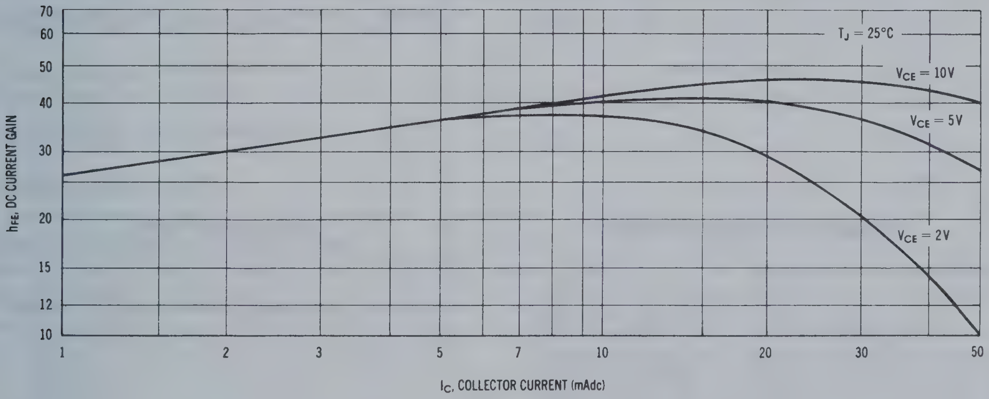
*PW $\leq$ 30 μs, Duty Cycle $\leq$ 1%

**PW $\leq$ 300 μs, Duty Cycle $\leq$ 2%

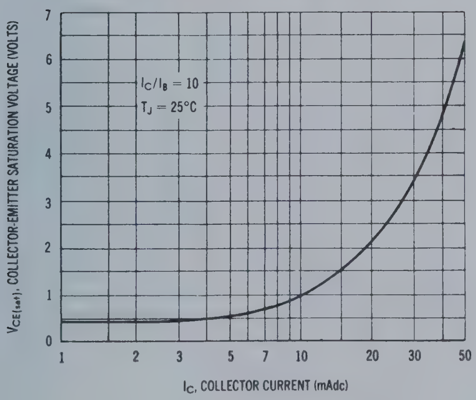
CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE



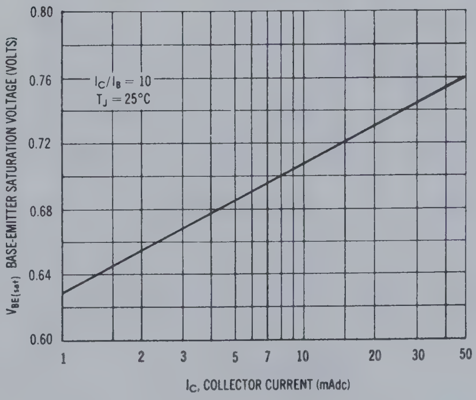
CURRENT GAIN CHARACTERISTICS versus COLLECTOR-EMITTER VOLTAGE



COLLECTOR-EMITTER SATURATION VOLTAGE



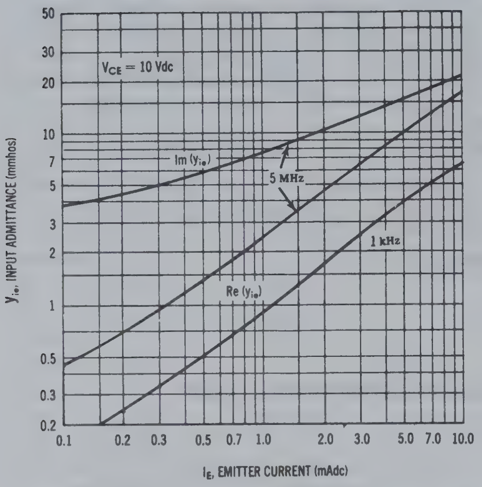
BASE -EMITTER SATURATION VOLTAGE



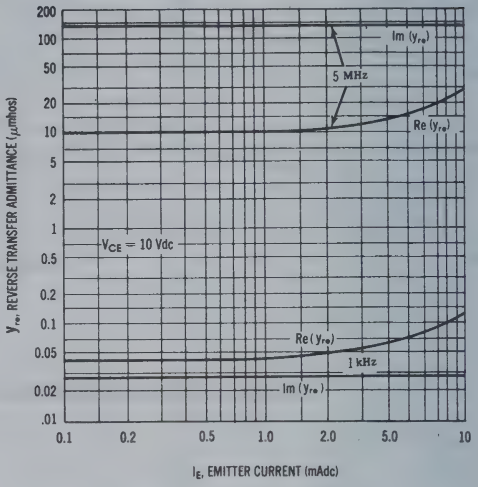
SMALL SIGNAL *y* PARAMETERS

$T_A = 25°C$

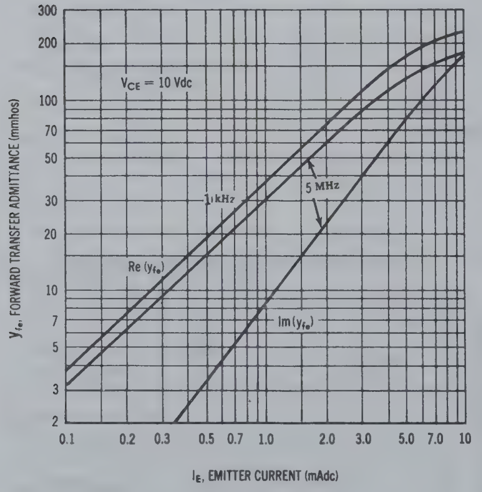
INPUT ADMITTANCE



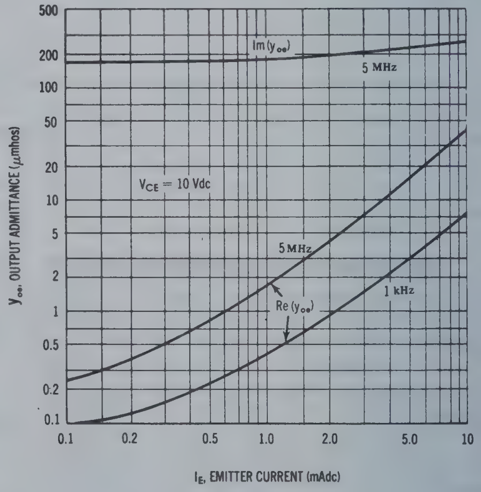
REVERSE TRANSFER ADMITTANCE



FORWARD TRANSFER ADMITTANCE



OUTPUT ADMITTANCE



2N3743 (SILICON)

CASE 79
(TO-39)

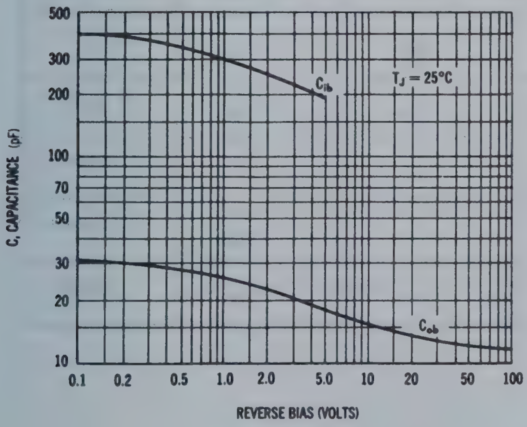
PNP silicon annular transistor for high-voltage amplifier applications from dc to VHF.

Collector connected to case

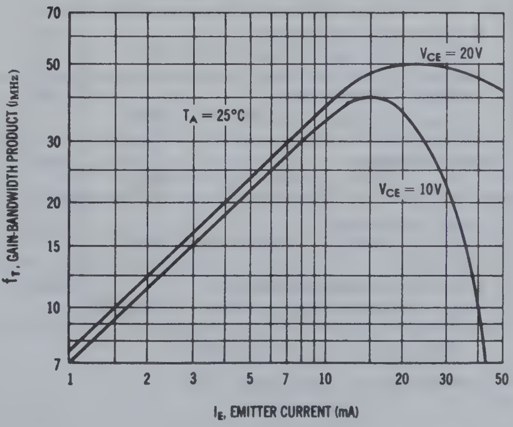
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	300	Vdc
Collector-Emitter Voltage	V_{CEO}	300	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate Above 25°C	P_D	1.0 5.7	Watt $mW/^oC$
Total Device Dissipation@ $T_C = 25^oC$ Derate Above 25^oC	P_D	5.0 28.6	Watts $mW/^oC$
Operating Junction Temperature	T_J	+200	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

JUNCTION CAPACITANCE



GAIN-BANDWIDTH PRODUCT



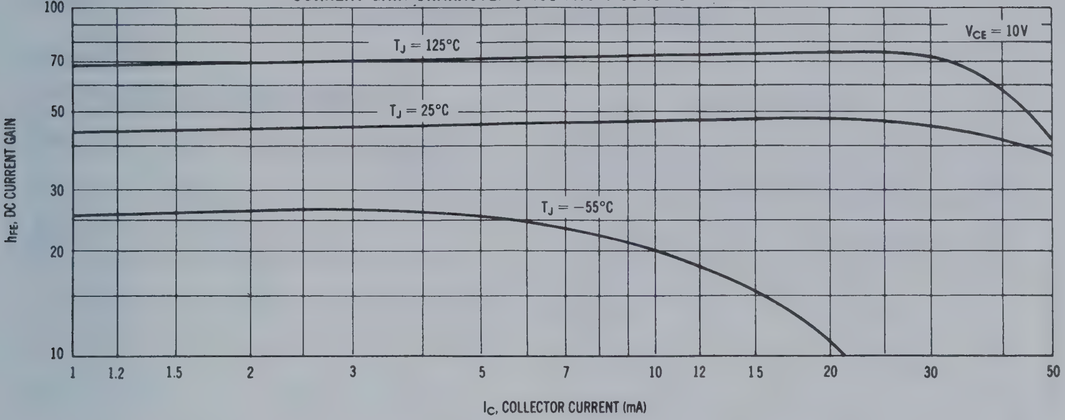
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	300	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	300	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Saturation Voltage**	$V_{CE(sat)}$**			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		—	5.0	
(I_C = 30 mAdc, I_B = 3 mAdc)		—	8.0	
Base-Emitter Saturation Voltage**	$V_{BE(sat)}$**			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		—	1.0	
(I_C = 30 mAdc, I_B = 3 mAdc)		—	1.2	
DC Forward Current Gain**	h_{FE}**			—
(I_C = 100 μAdc, V_{CE} = 10 Vdc)		20	—	
(I_C = 1 mAdc, V_{CE} = 10 Vdc)		25	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		25	—	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)		25	250	
(I_C = 50 mAdc, V_{CE} = 20 Vdc)		25	—	
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 200 Vdc, I_E = 0)		—	0.3	
(V_{CB} = 200 Vdc, I_E = 0, T_A = 100°C)		—	30	
Emitter-Base Leakage Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	0.1	μAdc
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 20MHz)	$\|h_{fe}\|$	1.5	—	—
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	15	pF
Input Capacitance (V_{EB} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	400	pF
Small Signal Current Gain (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{fe}	30	300	—
Voltage Feedback Ratio (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{re}	—	4.0	$X10^{-4}$
Input Impedance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{ie}	—	1.0	kohms
Output Admittance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{oe}	—	200	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 5 MHz)	$Re(h_{ie})$	—	40	ohms

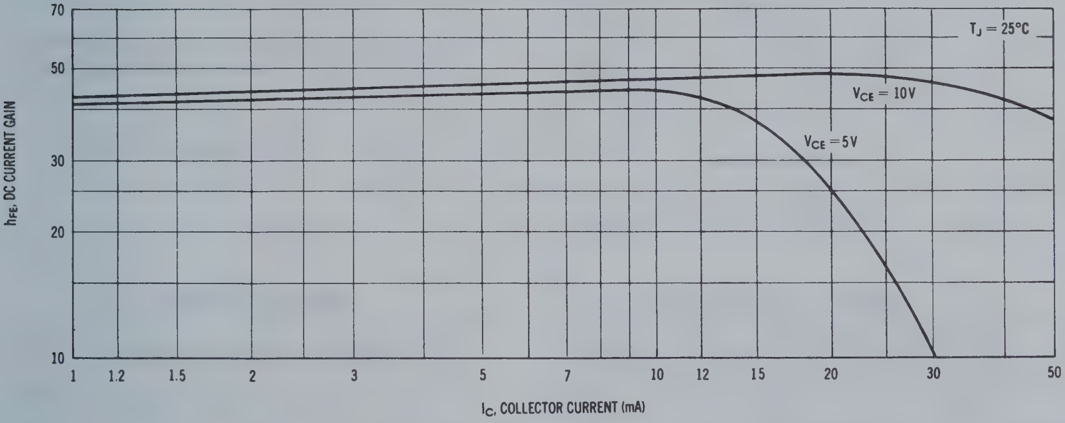
*PW ≤ 30 μs, Duty Cycle ≤ 1%

**PW ≤ 300 μs, Duty Cycle ≤ 2%

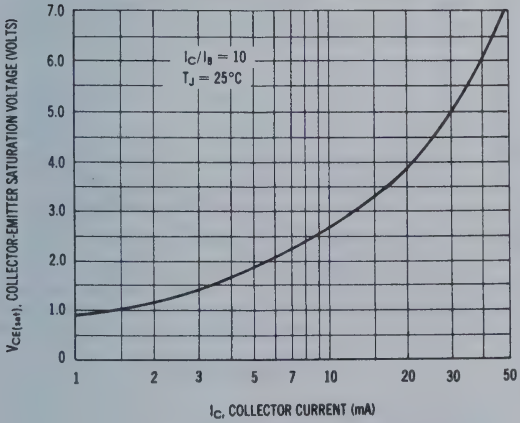
CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE



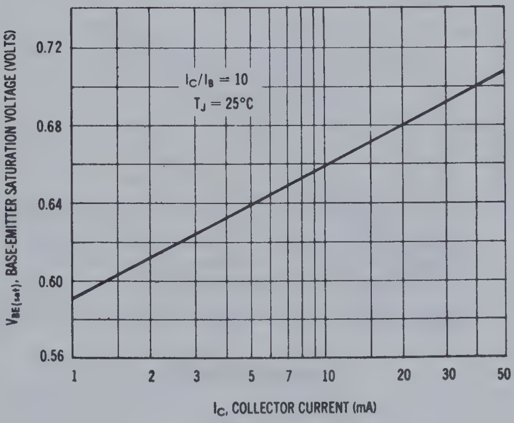
CURRENT GAIN CHARACTERISTICS versus COLLECTOR-EMITTER VOLTAGE



COLLECTOR-EMITTER SATURATION VOLTAGE



BASE-EMITTER SATURATION VOLTAGE

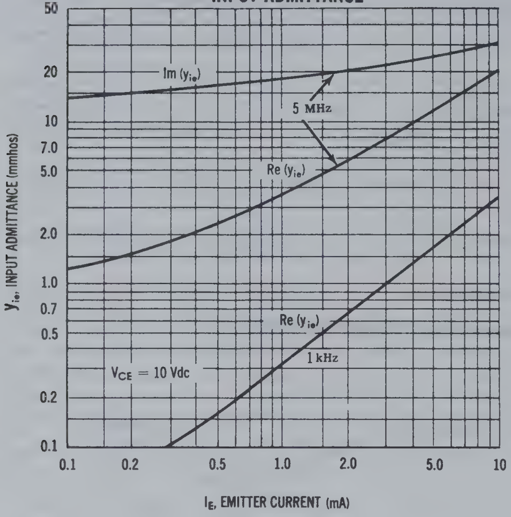


2N3743 (continued)

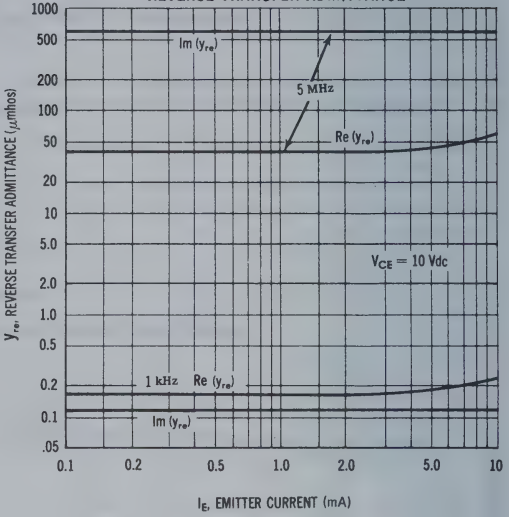
SMALL SIGNAL Y PARAMETERS

$T_A = 25°C$

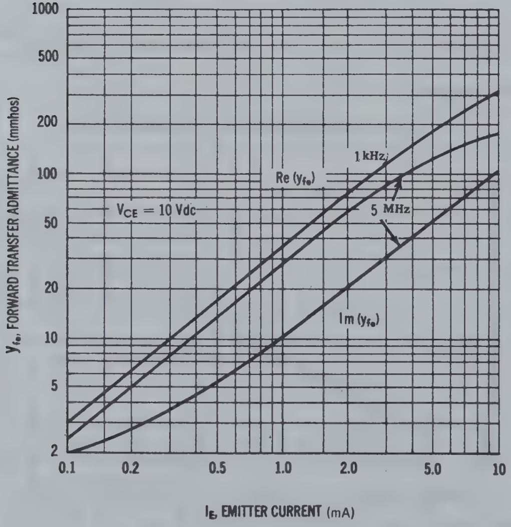
INPUT ADMITTANCE



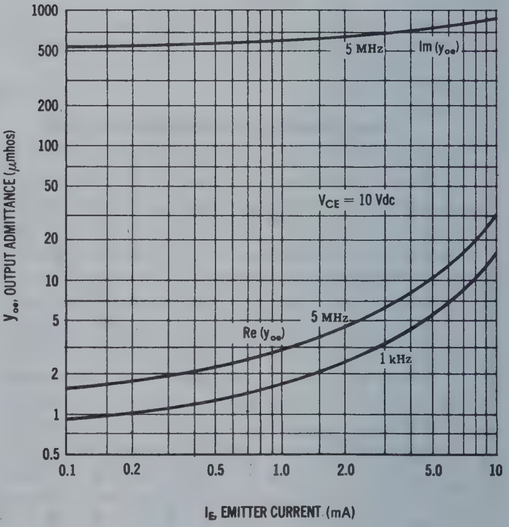
REVERSE TRANSFER ADMITTANCE



FORWARD TRANSFER ADMITTANCE



OUTPUT ADMITTANCE



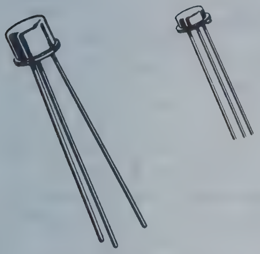
2N3762 (SILICON)
2N3763

2N3763 JAN, JTX AVAILABLE

2N3764
2N3765

2N3765 JAN, JTX AVAILABLE

Medium-current PNP silicon annular transistor, designed for high-speed switching and driver applications.



CASE 31
(TO-5)
2N3762
2N3763

CASE 26
(TO-46)
2N3764
2N3765

Collector connected to case

MAXIMUM RATINGS ($T_A = 25^oC$ unless otherwise noted)

Rating	Symbol	2N3762 2N3764	2N3763 2N3765	Unit
Collector-Base Voltage	V_{CB}	40	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.5		Adc
		TO-5 2N3762 2N3763	TO-46 2N3764 2N3765	
Total Device Dissipation @ $T_A = 25^oC$ Derating Factor Above 25^oC	P_D	1.0 5.71	0.5 2.86	Watt mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derating Factor Above 25^oC	P_D	4.0 22.8	2.0 11.4	Watts mW/^oC
Thermal Resistance Junction to Ambient Junction to Case	 θ_{JA} θ_{JC}	 0.175 0.044	 0.35 0.088	^oC/mW
Junction Temperature, Operating	T_J	+200		^oC
Storage Temperature Range	T_{stg}	-65 to +200		^oC

2N3762, 2N3763, 2N3764, 2N3765 (continued)

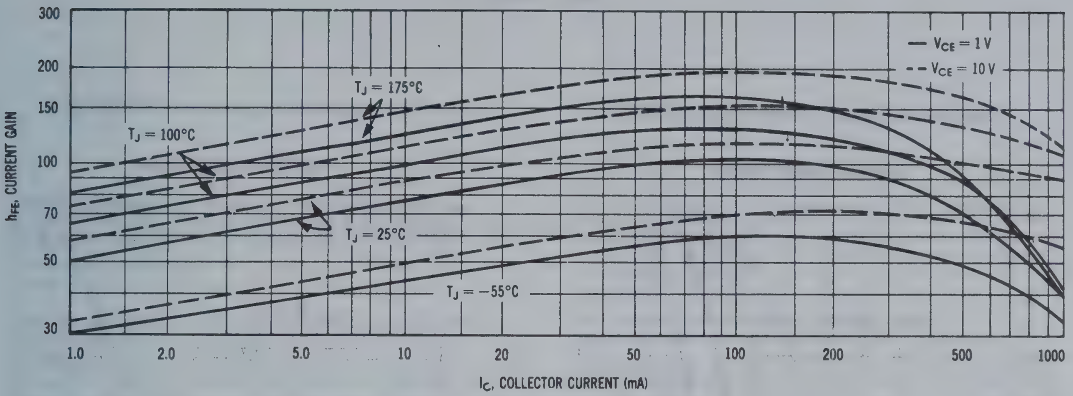
ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N3762, 2N3764 2N3763, 2N3765	BV_{CBO}	40 60	— —	Vdc
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, I_B = 0)	2N3762, 2N3764 2N3763, 2N3765	BV_{CEO}	40 60	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc, T_A = 100°C) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)	2N3762, 2N3764 2N3763, 2N3765	I_{CEX}	— — — —	0.10 10 0.10 10	μAdc
Base Cutoff Current (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc)	2N3762, 2N3764 2N3763, 2N3765	I_{BL}	— —	0.2 0.2	μAdc
ON CHARACTERISTICS					
DC Current Gain [1] (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 150 mAdc, V_{CE} = 1 Vdc) (I_C = 500 mAdc, V_{CE} = 1 Vdc) (I_C = 1 Adc, V_{CE} = 1.5 Vdc) (I_C = 1.5 Adc, V_{CE} = 5 Vdc)	 2N3762, 2N3764 2N3763, 2N3765 2N3762, 2N3764 2N3763, 2N3765	h_{FE}	35 40 35 30 20 30 20	— — — 120 80 — —	—
Collector Saturation Voltage [1] (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)		$V_{CE(sat)}$	— — — —	0.1 0.22 0.5 0.9	Vdc
Base-Emitter Saturation Voltage [1] (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)		$V_{BE(sat)}$	— — — 0.9	0.8 1.0 1.2 1.4	Vdc
TRANSIENT CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
High Frequency Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3762, 2N3764 2N3763, 2N3765	$\|h_{fe}\|$	1.8 1.5	— —	—
Delay Time	(V_{CC} = 30 V, $V_{BE(off)}$ = 2 V, I_C = 1 Amp, I_{B1} = 100 mA)	t_d	—	8.0	ns
Rise Time		t_r	—	35	ns
Storage Time	(V_{CC} = 30 V, I_C = 1 Amp, I_{B1} = -I_{B2} = 100 mA)	t_s	—	80	ns
Fall Time		t_f	—	35	ns
Total Control Charge (I_C = 1 Amp, I_B = 100 mA, V_{CC} = 30 V)		Q_T	—	30	nC

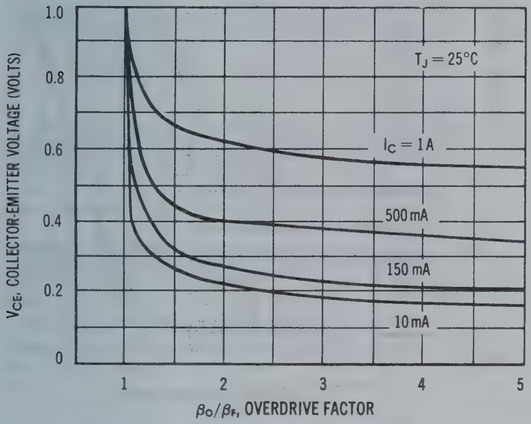
(1) Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

"ON" CONDITION CHARACTERISTICS

DC CURRENT GAIN



COLLECTOR SATURATION REGION

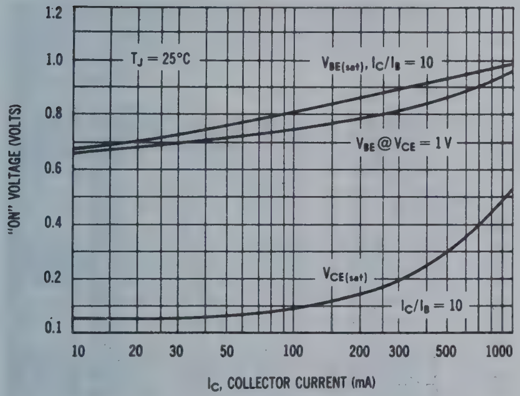


This graph shows the effect of base current on collector current. β_O (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3734, estimate a base current (I_{BF}) to ensure saturation at a temperature of 25°C and a collector of 500 mA.

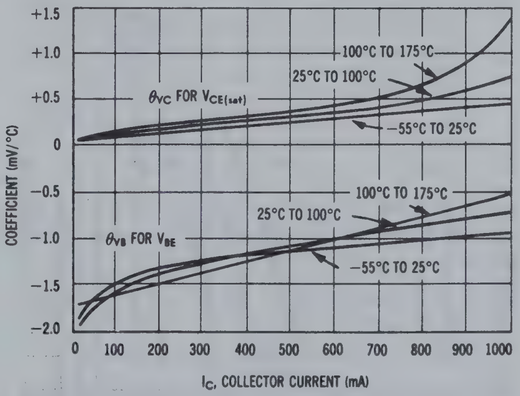
Observe that at I_C = 500 mA an overdrive factor of at least 2.0 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is typically 54 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design).

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE}\,@\,1\ \mathrm{Volt}}{I_C/I_{BF}} \qquad 2 = \frac{54}{500\ \mathrm{mA}/I_{BF}} \qquad I_{BF} \approx 18.5\ \mathrm{mA\ typ}$$

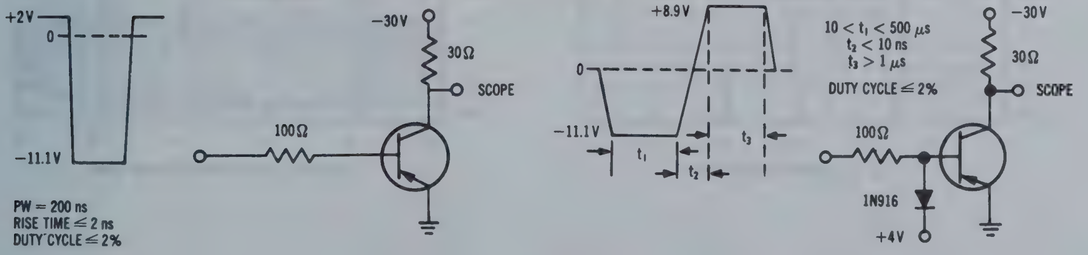
"ON" VOLTAGES



TEMPERATURE COEFFICIENTS

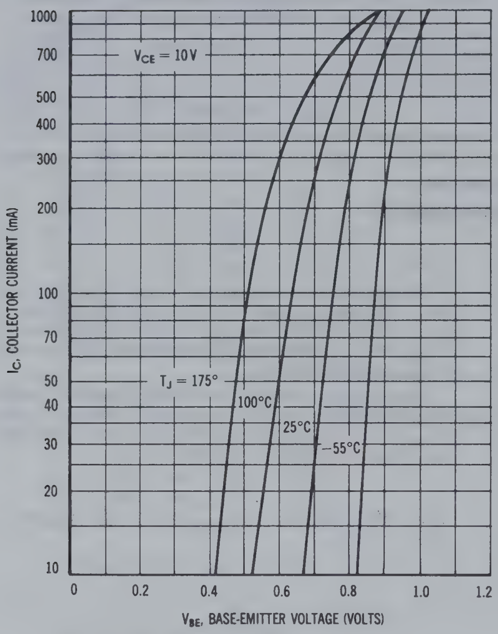


SWITCHING TIME EQUIVALENT TEST CIRCUITS

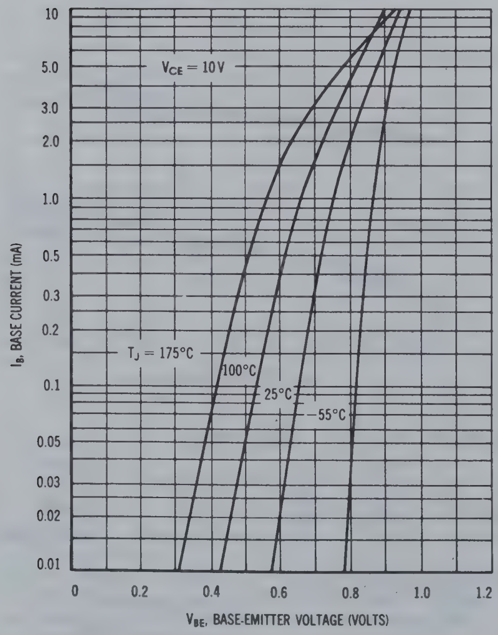

TURN-ON TIME
+2V
0
−11.1V
PW = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 2%
−30V
30Ω
SCOPE
100Ω
TURN-OFF TIME
+8.9V
0
−11.1V
t_1
t_2
t_3
10 < t_1 < 500 µs
t_2 < 10 ns
t_3 > 1 µs
DUTY CYCLE ≤ 2%
−30V
30Ω
SCOPE
100Ω
1N916
+4V

LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

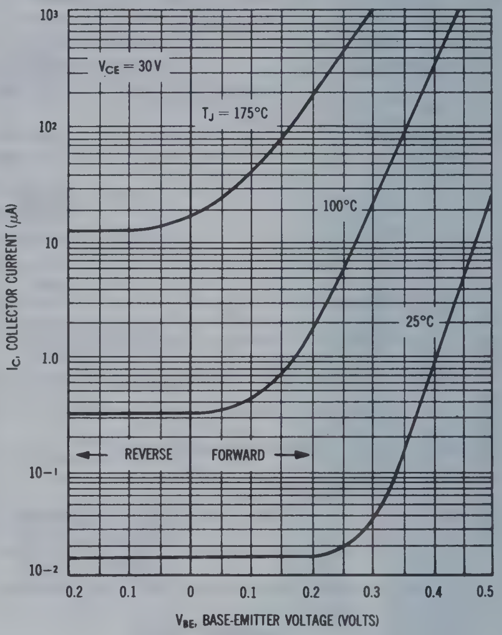


INPUT ADMITTANCE

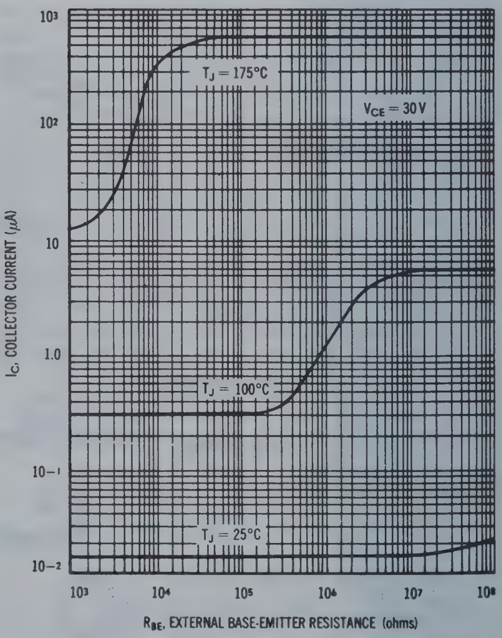


"OFF" CONDITION CHARACTERISTICS

TRANSCONDUCTANCE



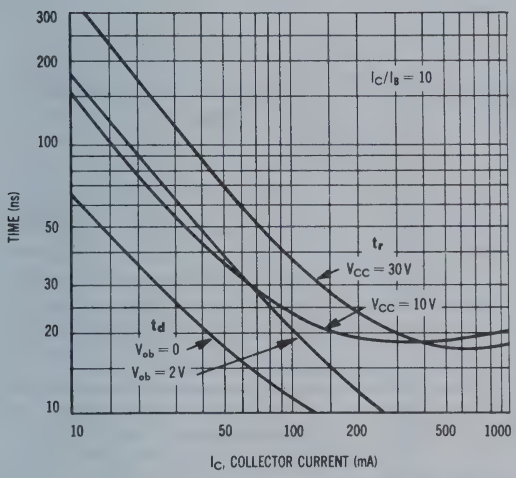
EFFECT OF BASE-EMITTER RESISTANCE



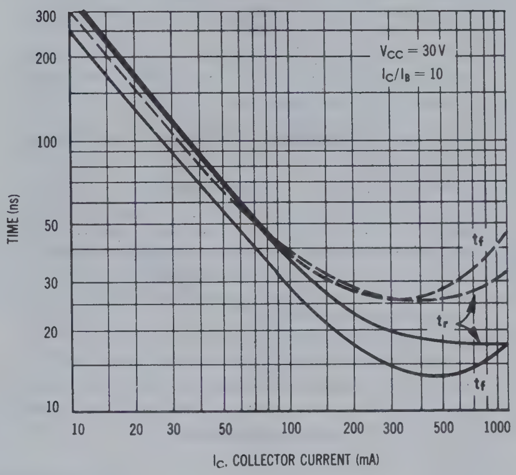
SWITCHING CHARACTERISTICS

— $T_J = 25°C$ -- $T_J = 150°C$

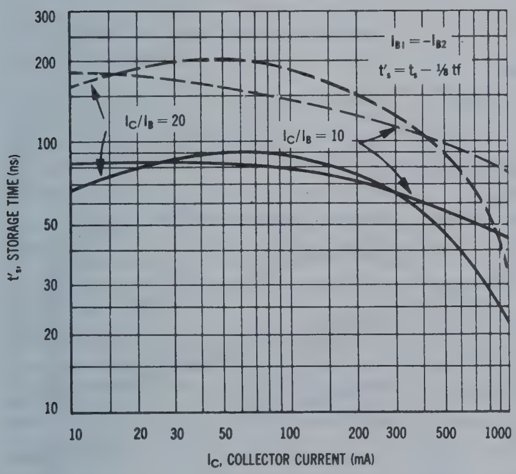
TURN-ON TIME



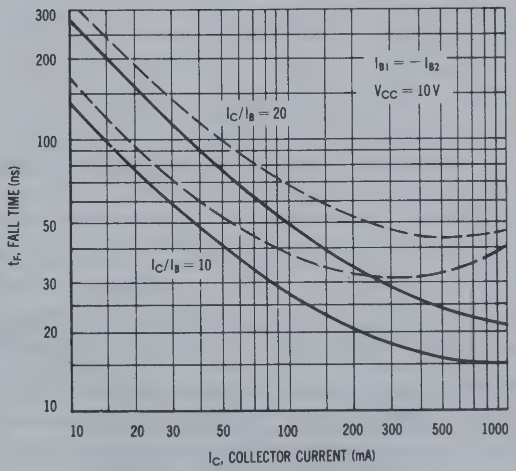
RISE AND FALL TIME



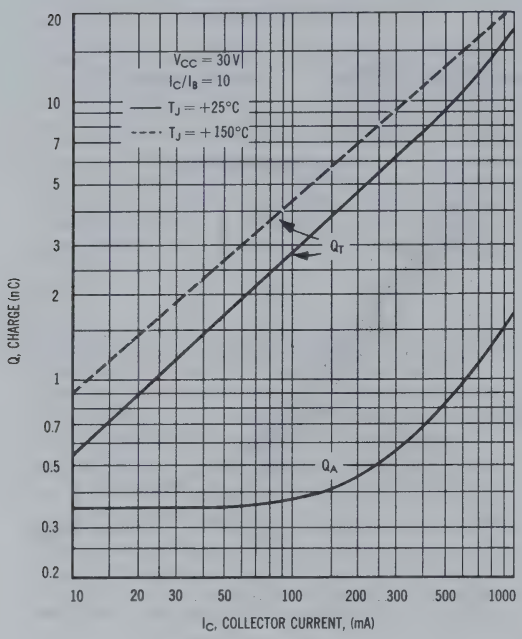
STORAGE TIME



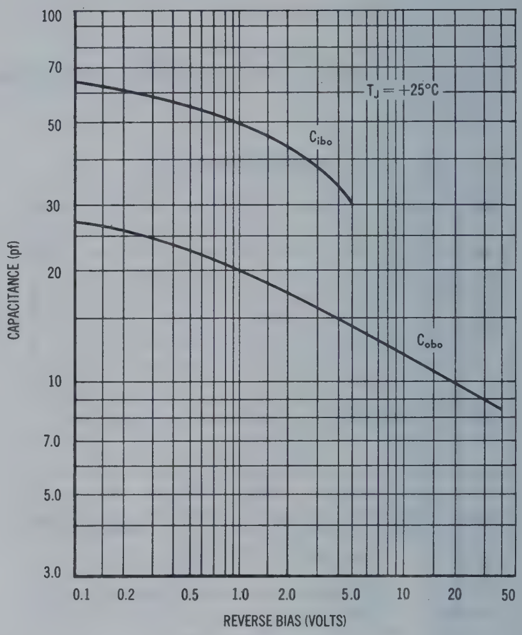
FALL TIME



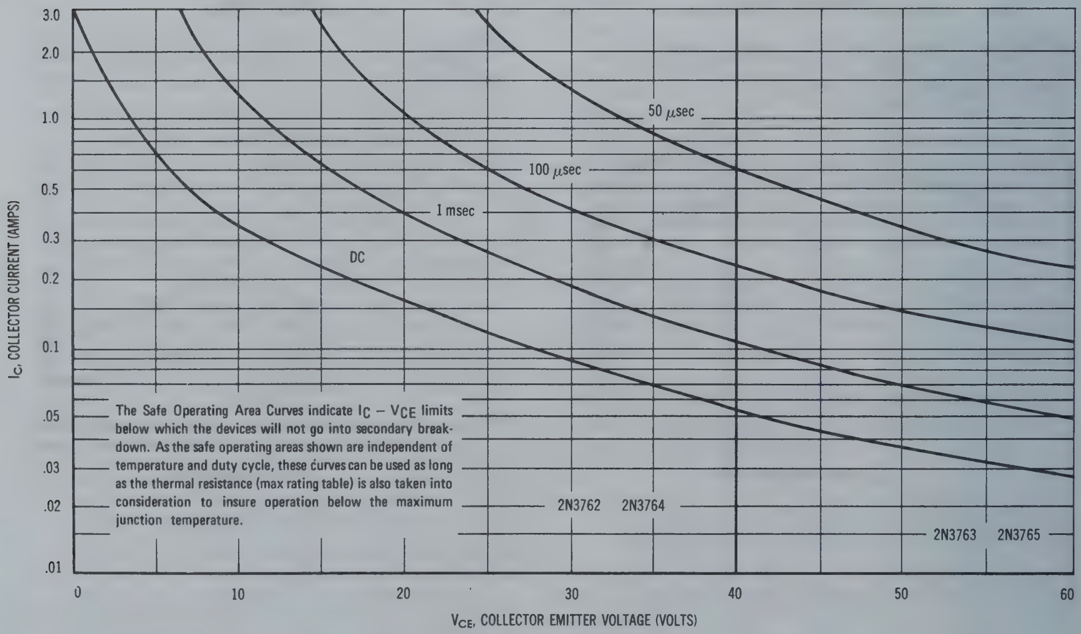
CHARGE DATA



CAPACITANCE

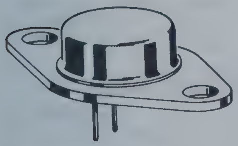


ACTIVE REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the thermal resistance (max rating table) is also taken into consideration to insure operation below the maximum junction temperature.

2N3766 (SILICON)
2N3767



CASE 80
(TO-66)

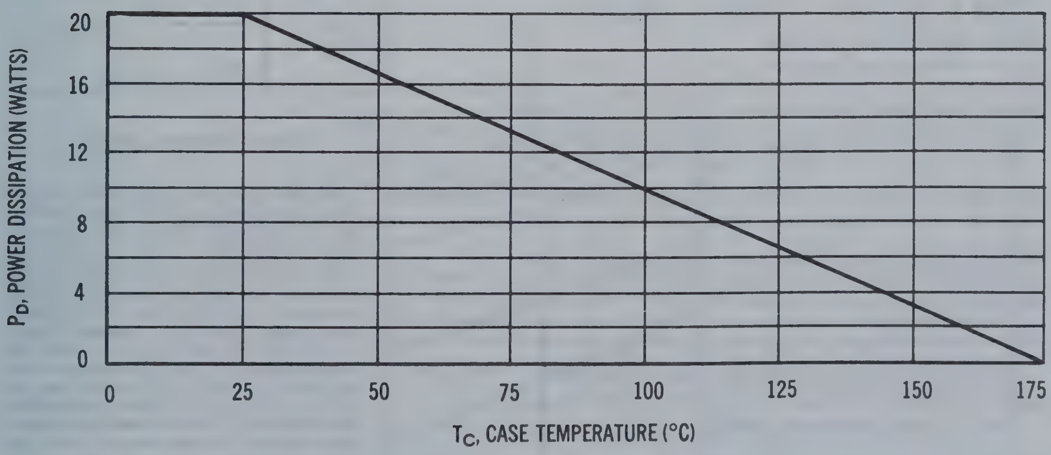
Collector connected to case

Medium-power NPN silicon transistors, for use in switching, and medium-power-amplifier applications. Complement to PNP 2N3740 (2N3766) 2N3741 (2N3767).

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	2N3766	2N3767	Unit
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0	6.0	Vdc
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector Current - Continuous Peak	I_C	4.0 4.0		Adc
Base Current	I_B	2.0		Adc
Total Device Dissipation @ T_C = 25° C Derate above 25° C	P_D	20 0.133		Watts W/°C
Thermal Resistance	θ_{JC}	7.5		°C/W
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to °175		°C

POWER-TEMPERATURE DERATING CURVE



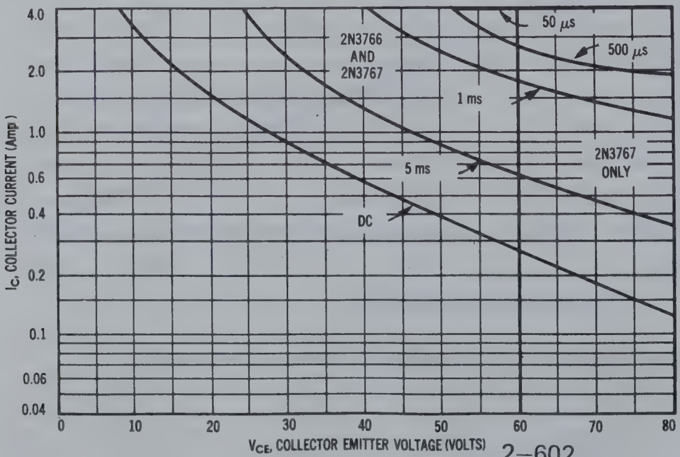
Safe area curves are indicated. Both limits are applicable and must be observed.

2N3766, 2N3767 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Voltage [1]		BV_{CEO}			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3766		60	—	
	2N3767		80	—	
Emitter-Base Cutoff Current (V_{EB} = 6 Vdc)		I_{EBO}	—	0.75	mAdc
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 80 Vdc, V_{BE} = 1.5 Vdc)	2N3766		—	0.1	
(V_{CE} = 100 Vdc, V_{BE} = 1.5 Vdc)	2N3767		—	0.1	
(V_{CE} = 50 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C)	2N3766		—	1.0	
(V_{CE} = 70 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C)	2N3767		—	1.0	
Collector-Emitter Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 60 Vdc, I_B = 0)	2N3766		—	0.7	
(V_{CE} = 80 Vdc, I_B = 0)	2N3767		—	0.7	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 80 Vdc, I_E = 0)	2N3766		—	0.1	
(V_{CB} = 100 Vdc, I_E = 0)	2N3767		—	0.1	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			—
(I_C = 50 mAdc, V_{CE} = 5 Vdc)			30	—	
(I_C = 500 mAdc, V_{CE} = 5 Vdc)			40	160	
(I_C = 1.0 Adc, V_{CE} = 10 Vdc)			20	—	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 1 Adc, I_B = 0.1 Adc)			—	2.5	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.0	
Base-Emitter Voltage (I_C = 1.0 Adc, V_{CE} = 10 Vdc)		V_{BE}	—	1.5	Vdc
TRANSIENT CHARACTERISTICS					
Current-Gain - Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)		f_T	10	—	MHz
Common-Base Output Capacitance (V_{CB} = 10 Vdc, I_C = 0 Adc, f = 100 kHz)		C_{ob}	—	50	pF
Small-Signal Current Gain (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)		h_{fe}	40	—	—

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%



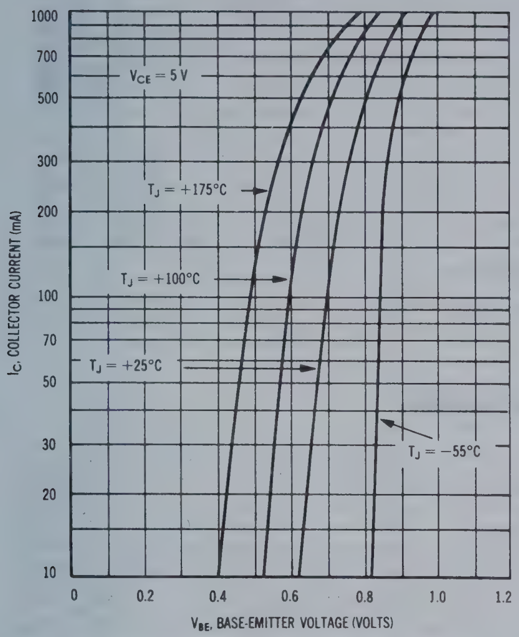
ACTIVE REGION SAFE AREAS

The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CEO} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

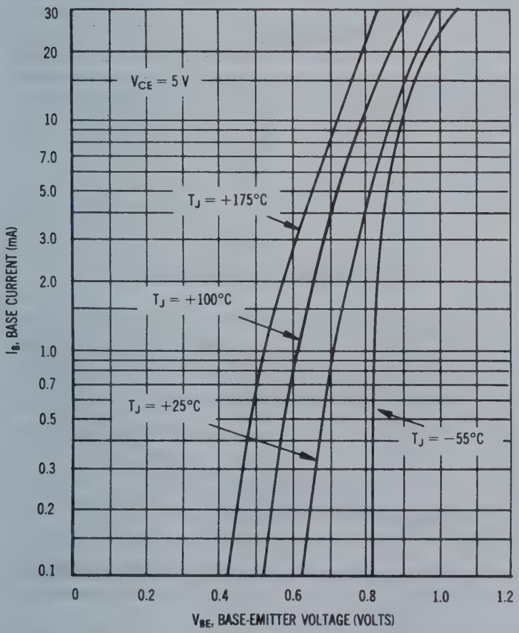
2N3766, 2N3767 (continued)

LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

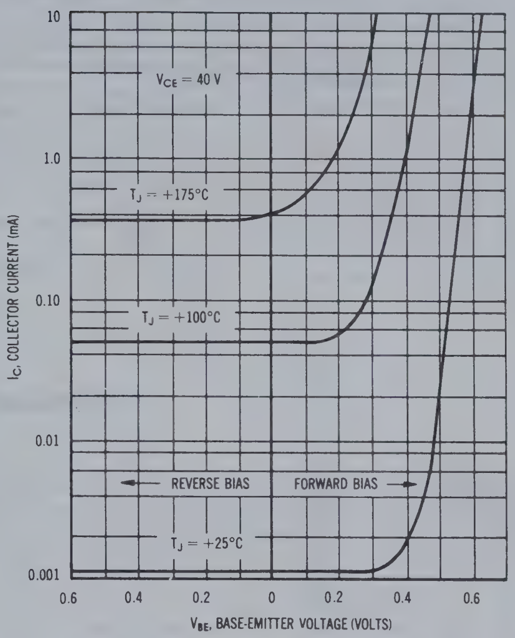


INPUT ADMITTANCE

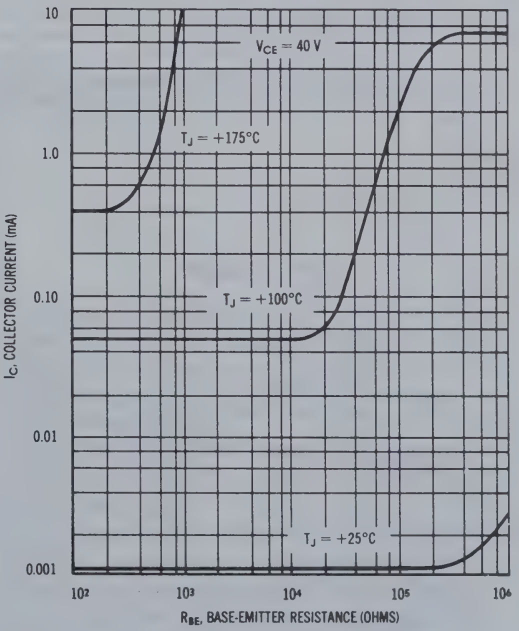


CUT-OFF CHARACTERISTICS

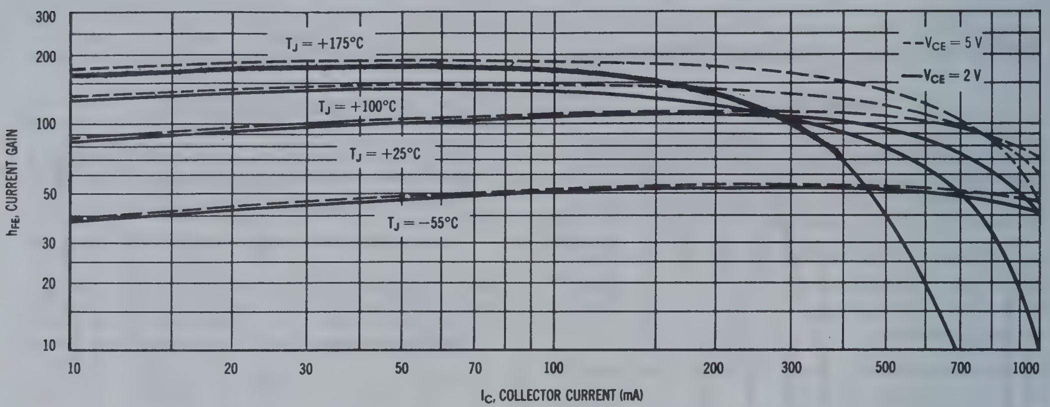
TRANSCONDUCTANCE



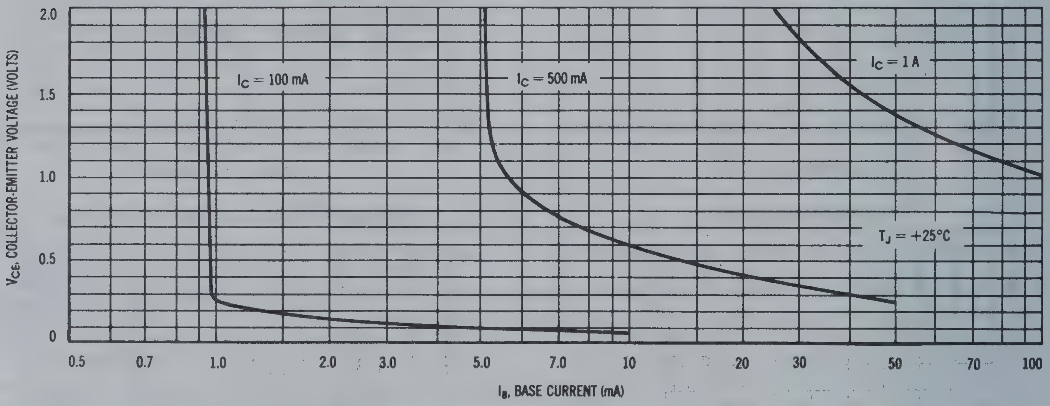
EFFECT OF BASE-EMITTER RESISTANCE



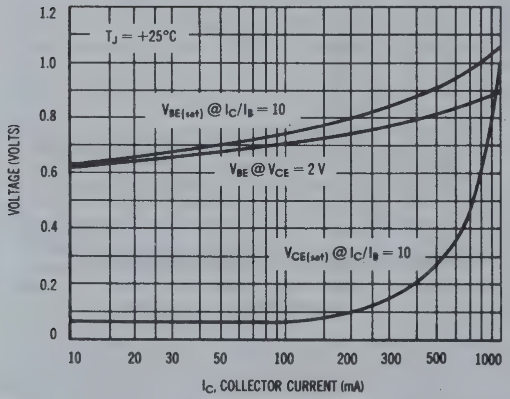
CURRENT GAIN



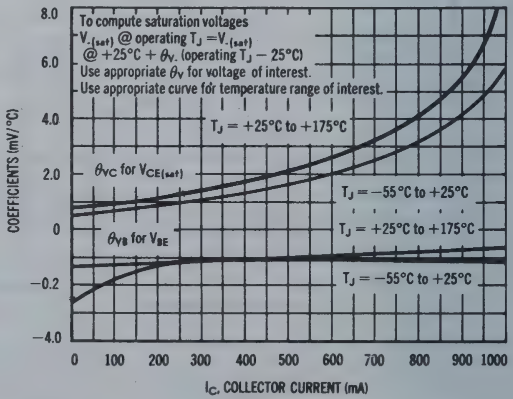
COLLECTOR SATURATION REGION



"ON" VOLTAGES



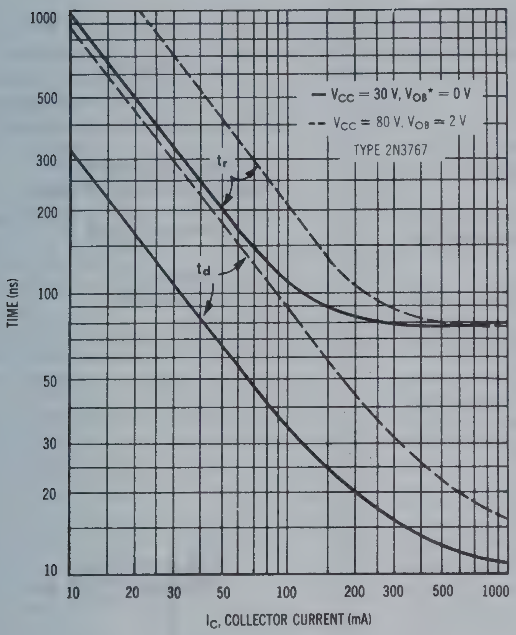
TEMPERATURE CO-EFFICIENTS



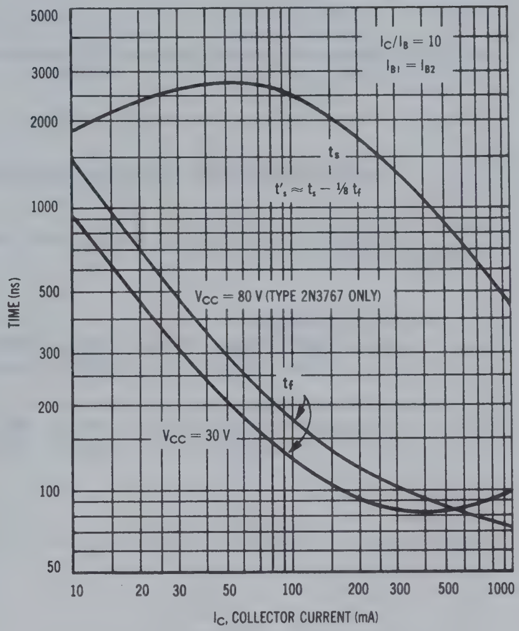
TRANSIENT CHARACTERISTICS

($T_J = 25°C$)

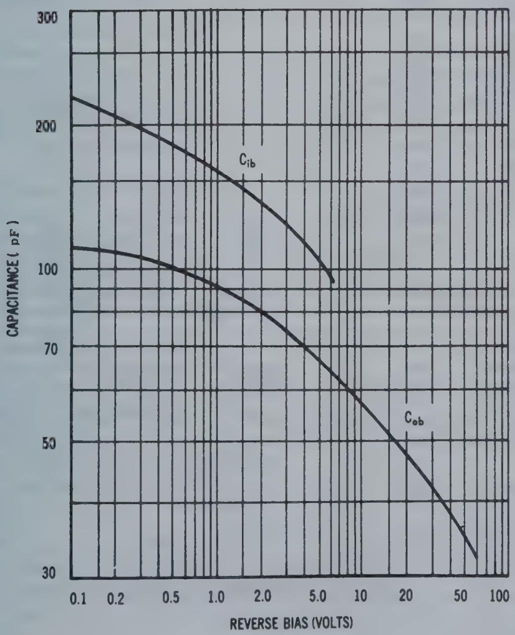
TURN-ON TIME



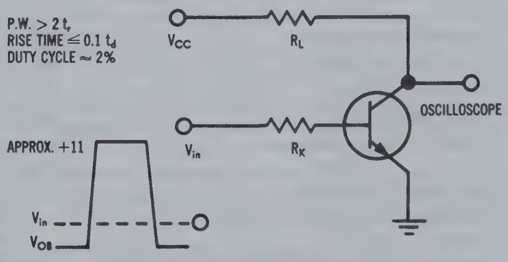
TURN-OFF TIME



CAPACITANCE



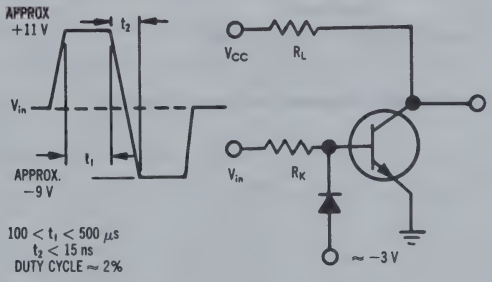
EQUIVALENT CIRCUIT FOR MEASURING DELAY AND RISE TIME



P.W. > 2 tr
RISE TIME ≤ 0.1 td
DUTY CYCLE ≈ 2%
VCC
RL
OSCILLOSCOPE
Vin
RK
APPROX. +11
Vin
VOB

*V_{OB} = BASE-EMITTER "OFF" BIAS VOLTAGE

EQUIVALENT CIRCUIT FOR MEASURING STORAGE AND FALL TIMES



APPROX
+11 V
t2
VCC
RL
Vin
t1
APPROX.
−9 V
Vin
RK
≈ −3 V
100 < t1 < 500 μs
t2 < 15 ns
DUTY CYCLE ≈ 2%

2N3771 (SILICON)
2N3772
MJ3771
MJ3772

HIGH-POWER NPN SILICON TRANSISTORS

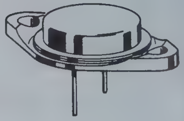
. . . designed for use in power amplifier and switching circuits applications.

- High DC Current Gain —
  h_{FE} = 15 (Min) @ I_C = 15 Adc — 2N3771, MJ3771
  15 (Min) @ I_C = 10 Adc — 2N3772, MJ3772
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 1.0 Vdc (Max) @ I_C = 15 Adc — MJ3771
  1.0 Vdc (Max) @ I_C = 10 Adc — MJ3772

20 AND 30 AMPERE
POWER TRANSISTORS

NPN SILICON

40-60 VOLTS
150 WATTS



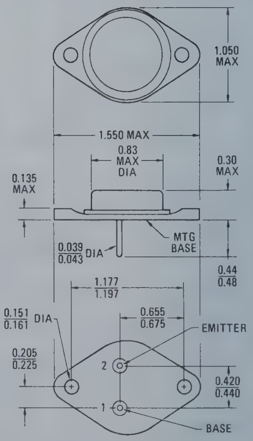
*MAXIMUM RATINGS

Rating	Symbol	2N3771 MJ3771	2N3772 MJ3772	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Collector-Emitter Voltage	V_{CEX}	50	80	Vdc
Collector-Base Voltage	V_{CB}	50	100	Vdc
Emitter-Base Voltage	V_{EB}	5.0	7.0	Vdc
Collector Current — Continuous Peak	I_C	30 30	20 30	Adc
Base Current — Continuous	I_B	7.5	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	150 0.86		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.17	°C/W

*Indicates JEDEC Registered Data (2N3771, 2N3772).


1.050 MAX
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
MTG BASE
0.039 / 0.043 DIA
0.44 / 0.48
1.177 / 1.197
0.151 / 0.161 DIA
0.655 / 0.675
EMITTER
0.205 / 0.225
2
0.420 / 0.440
1
BASE

CASE 11
TO-3

Collector Connected to Case

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
*Collector-Emitter Sustaining Voltage (Note 1)		$V_{CEO(sus)}$				Vdc
(I_C = 200 mAdc, I_B = 0)	2N3771, MJ3771		40	–	–	
	2N3772, MJ3772		60	–	–	
*Collector Cutoff Current		I_{CEO}				mAdc
(V_{CE} = 30 Vdc, I_B = 0)	2N3771, MJ3771		–	–	10	
(V_{CE} = 50 Vdc, I_B = 0)	2N3772, MJ3772		–	–	10	
*Collector Cutoff Current		I_{CEX}				mAdc
(V_{CE} = Rated V_{CB}, $V_{EB(off)}$ = 1.5 Vdc)	2N3771, MJ3771		–	–	2.0	
	2N3772, MJ3772		–	–	5.0	
(V_{CE} = 30 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	All Types		–	–	10	
Collector Cutoff Current		I_{CBO}				mAdc
*(V_{CB} = Rated V_{CB}, I_E = 0)	2N3771, MJ3771		–	–	2.0	
	2N3772, MJ3772		–	–	5.0	
(V_{CB} = 30 Vdc, I_E = 0, T_C = 150°C)	All Types		–	–	10	
*Emitter Cutoff Current		I_{EBO}				mAdc
(V_{BE} = Rated V_{BE}, I_C = 0)			–	–	5.0	
ON CHARACTERISTICS						
*DC Current Gain (Note 1)		h_{FE}				–
(I_C = 15 Adc, V_{CE} = 4.0 Vdc)	2N3771, MJ3771		15	–	60	
(I_C = 10 Adc, V_{CE} = 4.0 Vdc)	2N3772, MJ3772		15	–	60	
(I_C = 30 Adc, V_{CE} = 4.0 Vdc)	2N3771, MJ3771		5.0	–	–	
(I_C = 20 Adc, V_{CE} = 4.0 Vdc)	2N3772, MJ3772		5.0	–	–	
*Collector-Emitter Saturation Voltage (Note 1)		$V_{CE(sat)}$				Vdc
(I_C = 15 Adc, I_B = 1.5 Adc)	2N3771		–	–	2.0	
	MJ3771		–	–	1.0	
(I_C = 10 Adc, I_B = 1.0 Adc)	2N3772		–	–	1.4	
	MJ3772		–	–	1.0	
(I_C = 30 Adc, I_B = 6.0 Adc)	2N3771, MJ3771		–	–	4.0	
(I_C = 20 Adc, I_B = 4.0 Adc)	2N3772, MJ3772		–	–	4.0	
Base-Emitter Saturation Voltage (Note 1)		$V_{BE(sat)}$				Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)	MJ3771, MJ3772		–	–	1.7	
(I_C = 15 Adc, I_B = 1.5 Adc)	MJ3771, MJ3772		–	–	1.8	
(I_C = 20 Adc, I_B = 2.0 Adc)	MJ3771, MJ3772		–	–	2.5	
*Base-Emitter On Voltage (Note 1)		$V_{BE(on)}$				Vdc
(I_C = 15 Adc, V_{CE} = 4.0 Vdc)	2N3771		–	–	2.7	
	MJ3771		–	–	1.7	
(I_C = 10 Adc, V_{CE} = 4.0 Vdc)	2N3772		–	–	2.2	
	MJ3772		–	–	1.7	
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product		f_T				MHz
(I_C = 1.0 Adc, V_{CE} = 4.0 Vdc, f = 50 kHz)	2N3771, 2N3772		0.2	–	–	
(I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	MJ3771, MJ3772		2.0	–	–	
Small Signal Current Gain (I_C = 10 Adc, V_{CE} = 4.0 Vdc, f = 1.0 kHz)		h_{fe}	40	–	–	–
SWITCHING CHARACTERISTICS						
Rise Time	(V_{CC} = 10 Vdc, I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc) MJ3771, MJ3772	t_r	–	350	–	ns
Storage Time	MJ3771, MJ3772	t_s	–	700	–	ns
Fall Time	MJ3771, MJ3772	t_f	–	300	–	ns

*Indicates JEDEC Registered Data (2N3771, 2N3772).

Note 1: Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ACTIVE REGION DC SAFE OPERATING AREA

FIGURE 1 – 2N3771, 2N3772

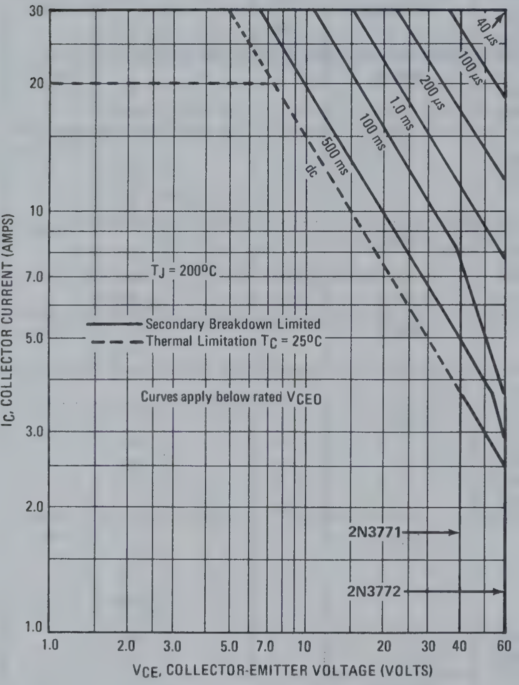
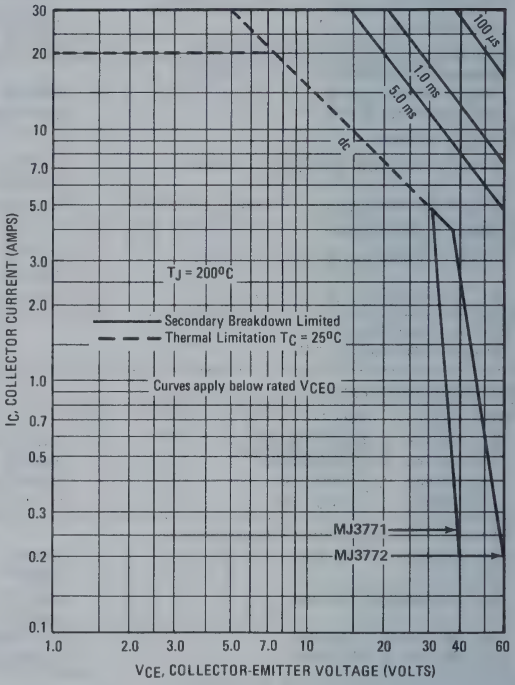
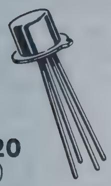


FIGURE 2 – MJ3771, MJ3772



The Safe Operating Area Curves indicate I_C–V_{CE} limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

2N3783 thru 2N3785
(GERMANIUM)



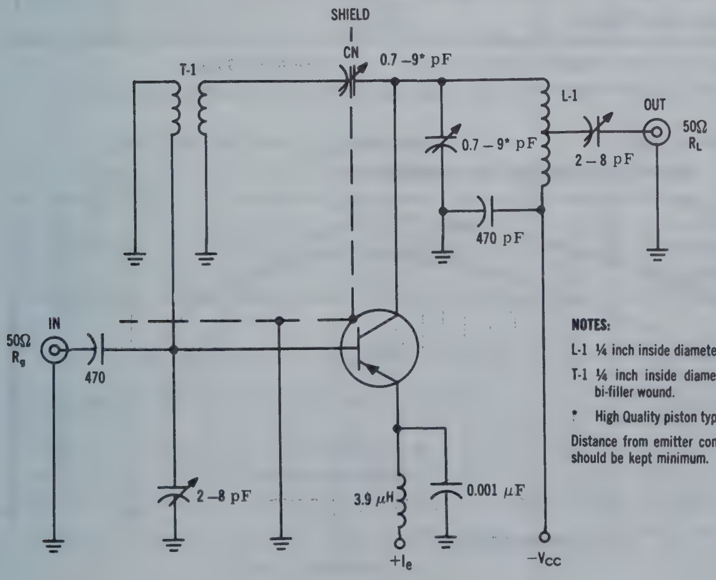
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for high-gain, low-noise amplifier, oscillator and frequency multiplier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3783 2N3784	2N3785	Unit
Collector-Base Voltage	V_{CB}	30	15	Vdc
Collector-Emitter Voltage	V_{CES}	30	15	Vdc
Collector-Emitter Voltage	V_{CEO}	20	12	Vdc
Emitter-Base Voltage	V_{EB}	0.5		Vdc
Collector Current	I_C	20		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0		mW mW/°C
Junction Operating & Storage Temperature Range	T_J, T_{stg}	-65 to +100		°C

FIGURE 1 — 200 MHz TEST CIRCUIT: POWER GAIN & NOISE FIGURE



NOTES:

L-1 ¼ inch inside diameter, ½ inch length, 4 turns #20 solid copper wire, center tapped.

T-1 ¼ inch inside diameter, close wound, 3 turns #26 solid copper wire. 1:1 ratio bi-filler wound.

* High Quality piston type capacitor.

Distance from emitter contact of transistor to ground side of bypass capacitor should be kept minimum.

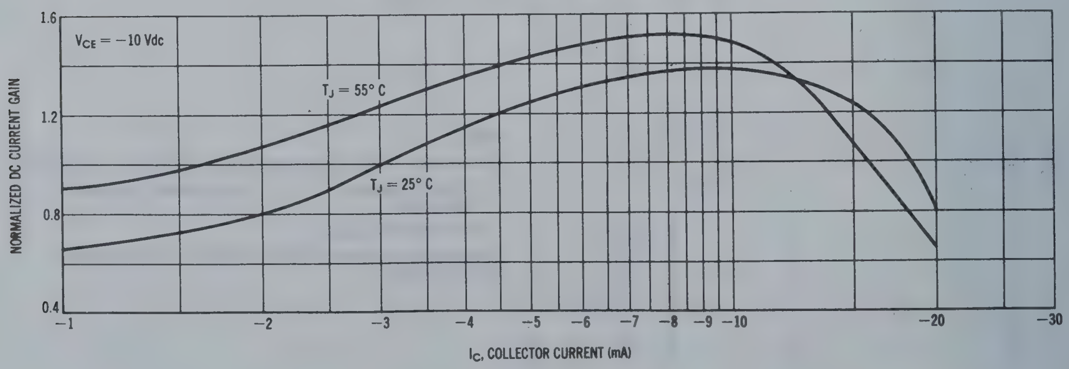
ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Test Conditions		Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 μAdc, I_E = 0	2N3783, 2N3784 2N3785	30 15	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 100 μAdc, V_{EB} = 0	2N3783, 2N3784 2N3785	30 15	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 2 mAdc, I_B = 0	2N3783, 2N3784 2N3785	20 12	— —	— —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 100 μAdc. I_C = 0	All Types	0.5	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0 V_{CB} = 10 Vdc, I_E = 0, T_A = +55^{o}C	All Types 2N3783, 2N3784	— —	— —	5.0 50	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	All Types	—	—	100	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 3 mAdc	2N3783, 2N3784 2N3785	20 15	— —	200 200	—
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 5.0 mAdc, I_B = 1.0 mAdc	2N3783, 2N3784 2N3785	— —	— —	0.25 0.35	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 5.0 mAdc, I_B = 1.0 mAdc	2N3783, 2N3784 2N3785	— —	— —	0.55 0.65	Vdc
Small-Signal Forward Current Transfer Ratio	h_{fe}	I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 1 kHz	2N3783, 2N3784 2N3785	20 15	— —	200 200	—
Current Gain - Bandwidth Product	f_τ	I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 200 MHz	2N3783 2N3784, 2N3785	800 700	— —	1600 1600	MHz
Collector-Base Time Constant	r'_bC_c	V_{CB} = 10 Vdc, I_E = 3 mAdc, f = 31.8 MHz	2N3783, 2N3784 2N3785	1.0 1.0	— —	6.0 10	ps
Collector-Base Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	2N3783, 2N3784 2N3785	— —	— —	1.0 1.2	pF
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 200 MHz	2N3783, 2N3784 2N3785	20 18	— —	33 33	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 200 MHz R_G = 50 ohms	2N3783 2N3784 2N3785	— — —	— — —	2.2 2.5 2.9	dB
Power Gain (AGC) Note 1	G_e(AGC)	V_{CE} = 10 Vdc, I_C = 15 mAdc, f = 200 MHz	2N3783 2N3784, 2N3785	— —	— 0	0 —	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 1000 MHz R_G = 50 ohms (Note 2)	2N3783 2N3784 2N3785	— — —	— 7.0 7.5	6.5 — —	dB

NOTE 1: AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3 mAdc.

NOTE 2: This Noise Figure was obtained using Hewlett-Packard Type 342A Noise Figure Meter and Type 349A Noise Source.

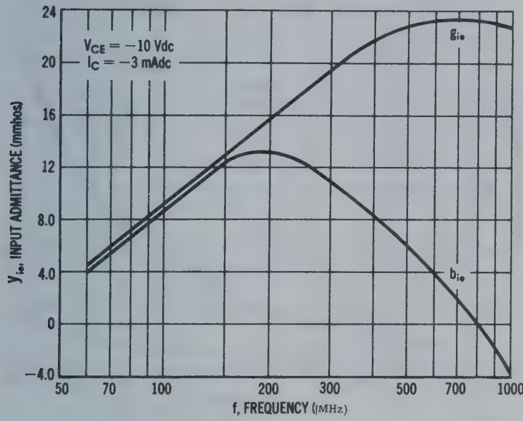
NORMALIZED DC CURRENT GAIN CHARACTERISTICS



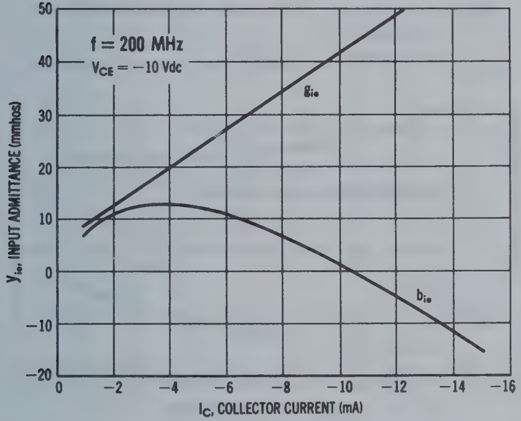
y_{ie}, INPUT ADMITTANCE CHARACTERISTICS

($T_A = 25°$ C unless otherwise noted)

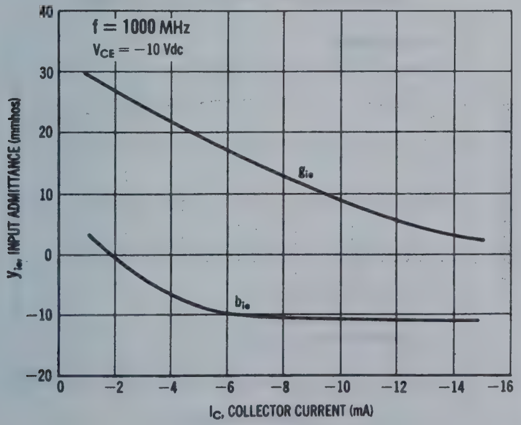
INPUT ADMITTANCE versus FREQUENCY



INPUT ADMITTANCE versus COLLECTOR CURRENT



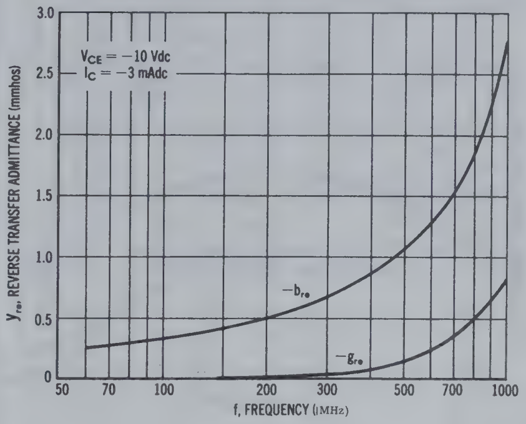
INPUT ADMITTANCE versus COLLECTOR CURRENT



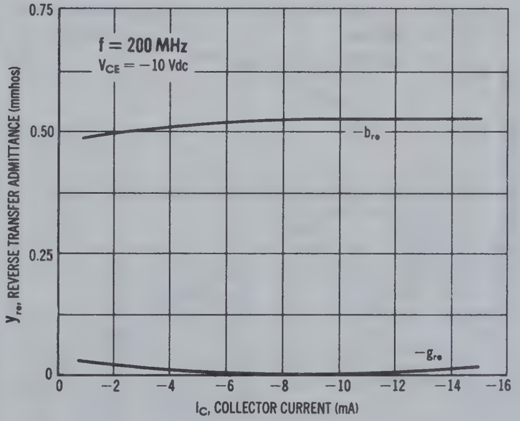
y_{re}, REVERSE TRANSFER ADMITTANCE CHARACTERISTICS

($T_A = 25°$ C unless otherwise noted)

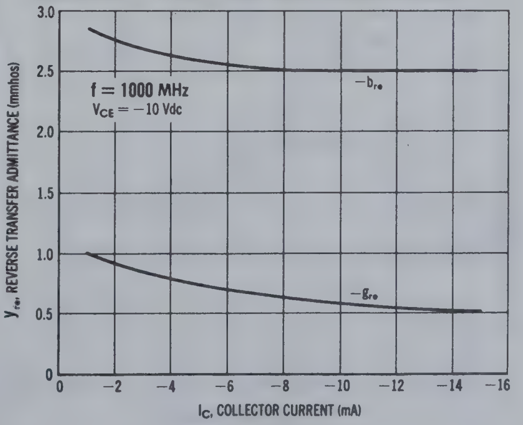
REVERSE TRANSFER ADMITTANCE versus FREQUENCY



REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT



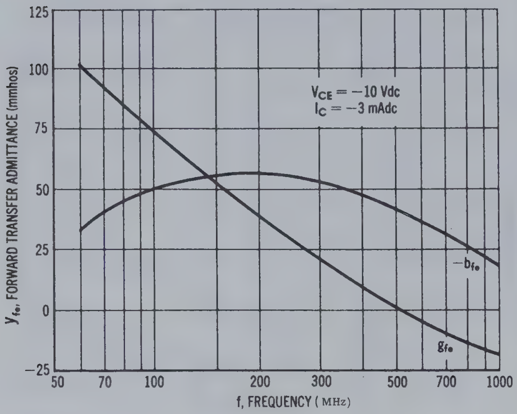
REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT



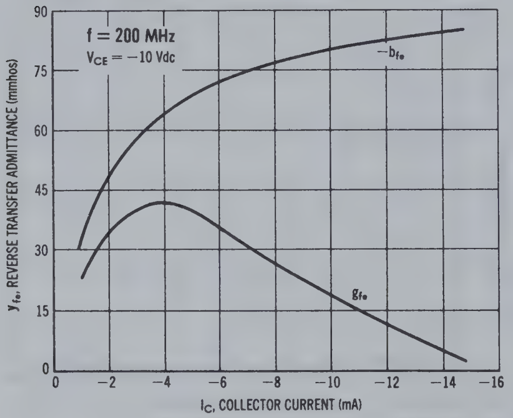
y_{fe}, FORWARD TRANSFER ADMITTANCE CHARACTERISTICS

(T_A = 25° C unless otherwise noted)

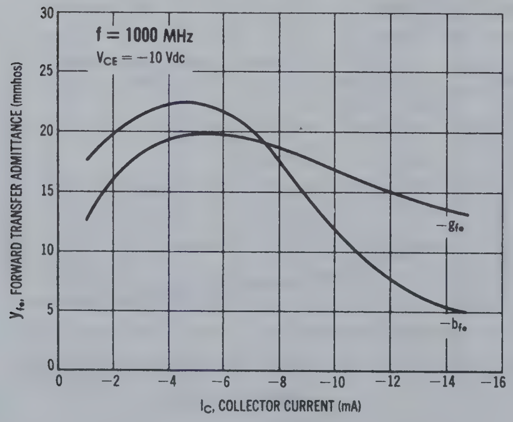
FORWARD TRANSFER ADMITTANCE versus FREQUENCY



FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT



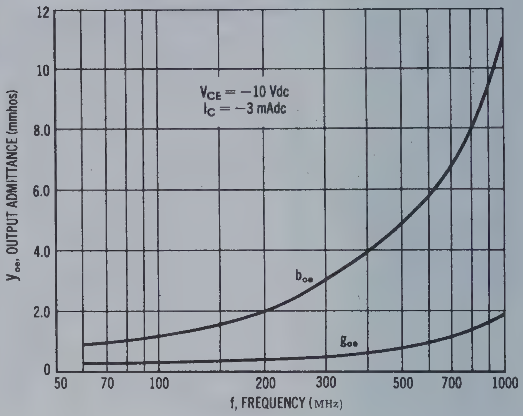
FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT



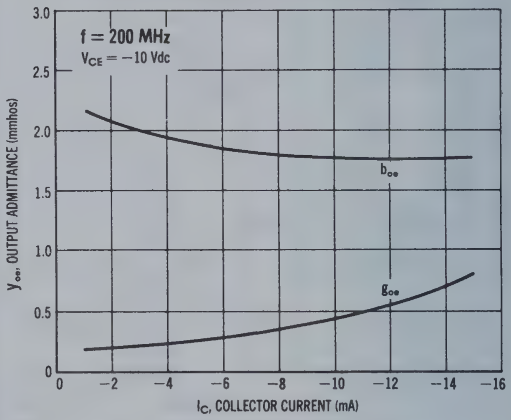
y_{oe}, OUTPUT ADMITTANCE CHARACTERISTICS

(T_A = 25° C unless otherwise noted)

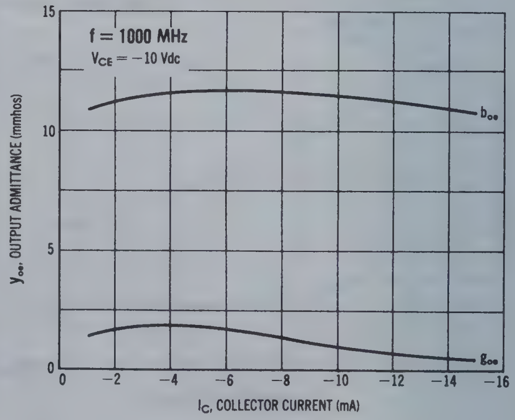
OUTPUT ADMITTANCE versus FREQUENCY

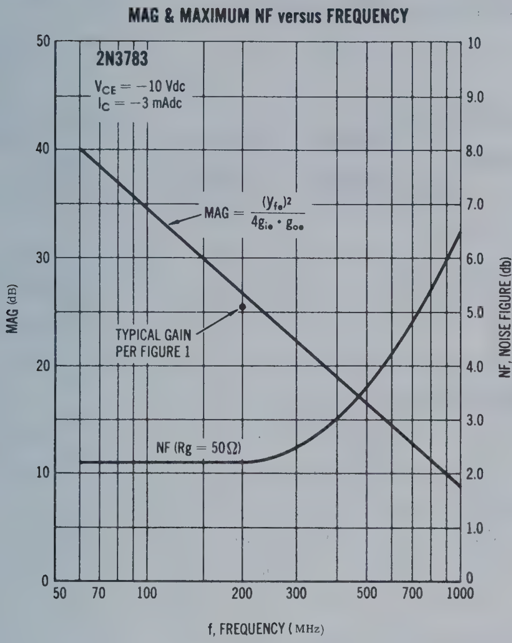


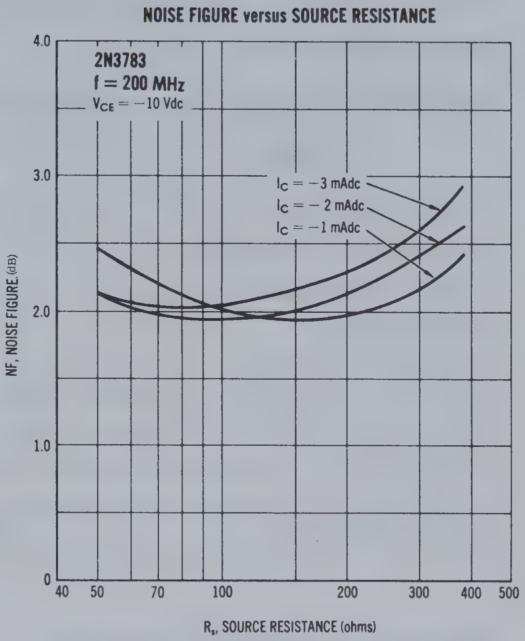
OUTPUT ADMITTANCE versus COLLECTOR CURRENT

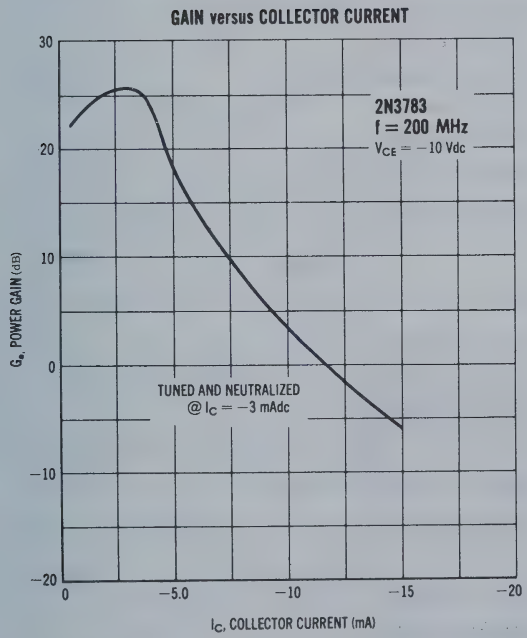


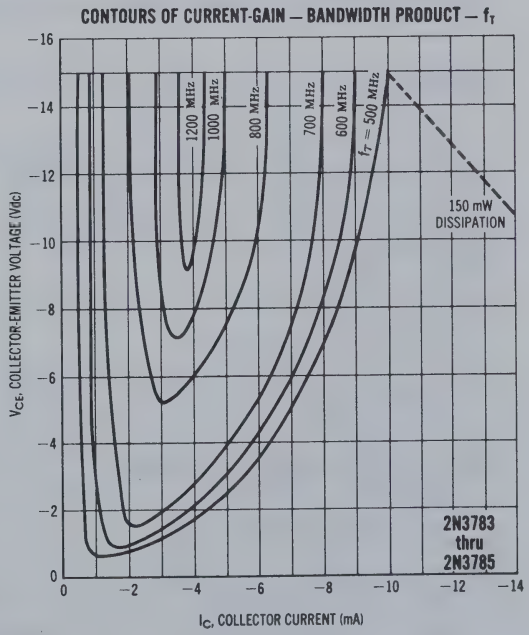
OUTPUT ADMITTANCE versus COLLECTOR CURRENT



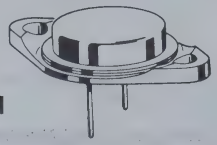

MAG & MAXIMUM NF versus FREQUENCY
2N3783
$V_{CE} = -10$ Vdc
$I_C = -3$ mAdc
MAG = $\frac{(y_{fe})^2}{4g_{ie} \cdot g_{oe}}$
TYPICAL GAIN PER FIGURE 1
NF (Rg = 50Ω)
MAG (dB)
NF, NOISE FIGURE (db)
f, FREQUENCY (MHz)
50
40
30
20
10
0
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
50
70
100
200
300
500
700
1000


NOISE FIGURE versus SOURCE RESISTANCE
2N3783
f = 200 MHz
$V_{CE} = -10$ Vdc
$I_C = -3$ mAdc
$I_C = -2$ mAdc
$I_C = -1$ mAdc
NF, NOISE FIGURE (dB)
R_s, SOURCE RESISTANCE (ohms)
4.0
3.0
2.0
1.0
0
40
50
70
100
200
300
400
500


GAIN versus COLLECTOR CURRENT
2N3783
f = 200 MHz
$V_{CE} = -10$ Vdc
TUNED AND NEUTRALIZED
@ $I_C = -3$ mAdc
G_e, POWER GAIN (dB)
I_C, COLLECTOR CURRENT (mA)
30
20
10
0
−10
−20
0
−5.0
−10
−15
−20


CONTOURS OF CURRENT-GAIN — BANDWIDTH PRODUCT — f_T
1200 MHz
1000 MHz
800 MHz
700 MHz
600 MHz
f_T = 500 MHz
150 mW DISSIPATION
2N3783 thru 2N3785
V_{CE}, COLLECTOR-EMITTER VOLTAGE (Vdc)
I_C, COLLECTOR CURRENT (mA)
−16
−14
−12
−10
−8
−6
−4
−2
0
0
−2
−4
−6
−8
−10
−12
−14

2N3789 thru 2N3792 (SILICON)



CASE 11
(TO-3)

Collector connected to case

PNP silicon power transistors for medium-speed switching and amplifier applications. Complement to NPN type 2N3713 thru 2N3716.

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

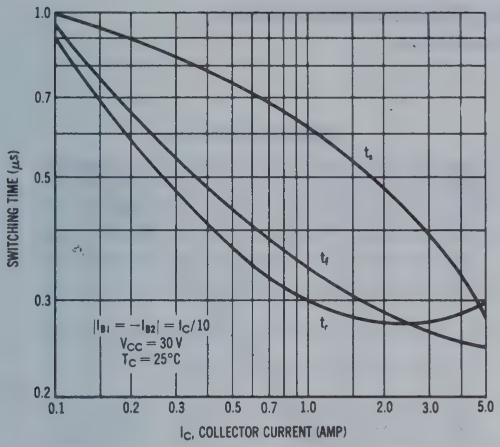
Rating	Symbol	2N3789 2N3791	2N3790 2N3792	Unit
Collector-Base Voltage	V_{CB}	60	80	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	7.0	7.0	Volts
Collector Current	I_C	10	10	Amp
Collector Current (Peak)	I_C	10	10	Amp
Base Current (Continuous)	I_B	4.0	4.0	Amp
Power Dissipation	P_D	150	150	Watts
Thermal Resistance	θ_{JC}	1.17	1.17	°C/W
Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C

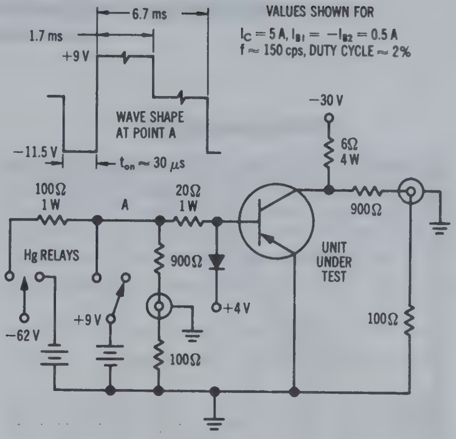
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage*		$V_{CEO(sus)}$*			Vdc
(I_C = 200 mAdc, I_B = 0)	2N3789, 2N3791		60	—	
	2N3790, 2N3792		80	—	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc)	2N3789, 2N3791		—	1.0	
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc)	2N3790, 2N3792		—	1.0	
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3789, 2N3791		—	5.0	
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3790, 2N3792		—	5.0	
Emitter-Base Cutoff Current (V_{EB} = 7 Vdc)		I_{EBO}	—	5.0	mAdc
DC Current Gain*		h_{FE}*			—
(I_C = 1 Adc, V_{CE} = 2 Vdc)	2N3789, 2N3790		25	90	
	2N3791, 2N3792		50	150	
(I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3789, 2N3790		15	—	
	2N3791, 2N3792		30	—	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 4 Adc, I_B = 0.4 Adc)	2N3789, 2N3790		—	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3791, 2N3792		—	1.0	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 4 Adc, I_B = 0.4 Adc)	2N3789, 2N3790		—	2.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3791, 2N3792		—	1.5	
Current Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 0.5 Adc f = 1.0 MHz)		f_T	4.0	—	MHz

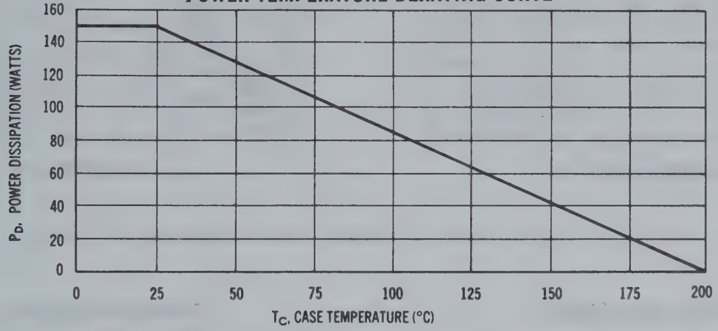
*Sweep Test: 1/2 sine wave cycle @ 60 Hz .

TYPICAL SWITCHING TIMES AND TEST CIRCUIT



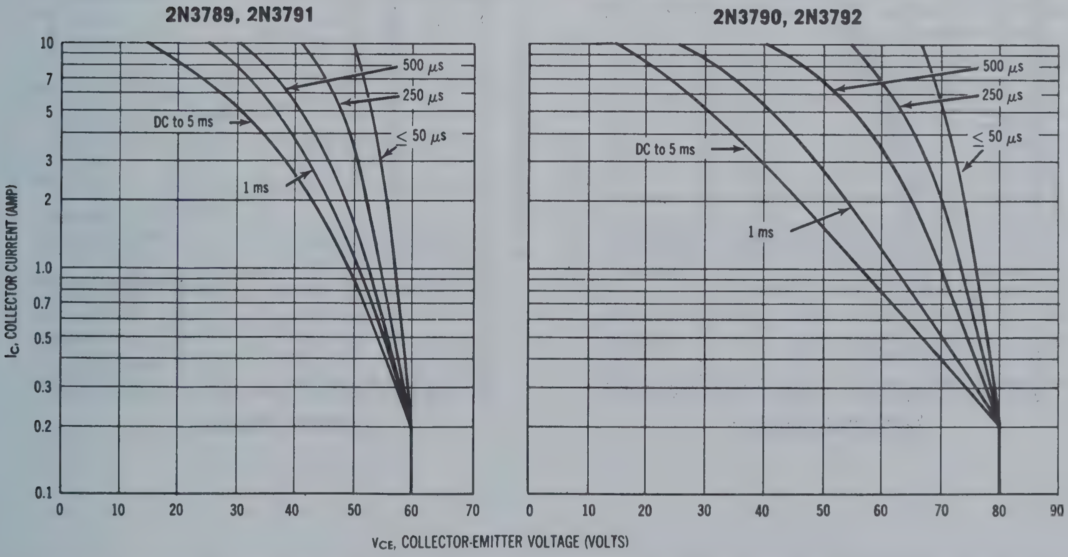

6.7 ms
1.7 ms
+9 V
−11.5 V
WAVE SHAPE AT POINT A
t_on ≈ 30 µs
VALUES SHOWN FOR
IC = 5 A, IB1 = −IB2 = 0.5 A
f ≈ 150 cps, DUTY CYCLE ≈ 2%
−30 V
6Ω 4 W
100Ω 1 W
A
20Ω 1 W
900Ω
Hg RELAYS
900Ω
+4 V
UNIT UNDER TEST
−62 V
+9 V
100Ω
100Ω

POWER-TEMPERATURE DERATING CURVE



Safe area curves are indicated. Both limits are applicable and must be observed.

ACTIVE-REGION SAFE OPERATING AREAS


2N3789, 2N3791

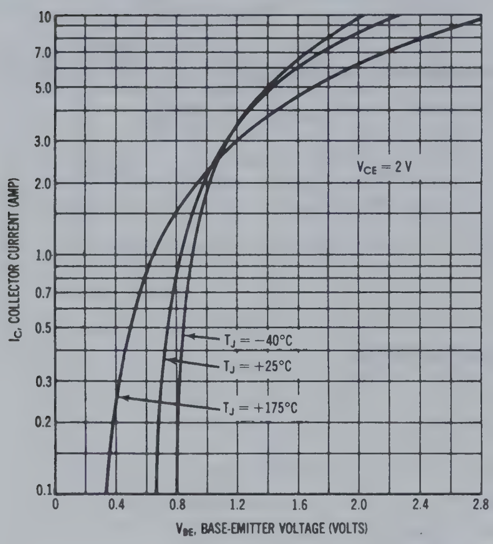
2N3790, 2N3792

The Safe Operating Area Curves indicate I_C - V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursion make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

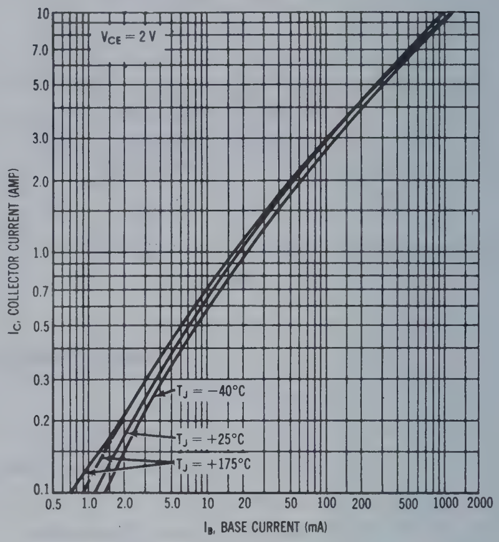
LARGE SIGNAL CHARACTERISTICS – TYPE 2N3789, 2N3790

(PULSE TEST: pulse width ≈ 200 μs, duty cycle ≈ 1%)

TRANSCONDUCTANCE

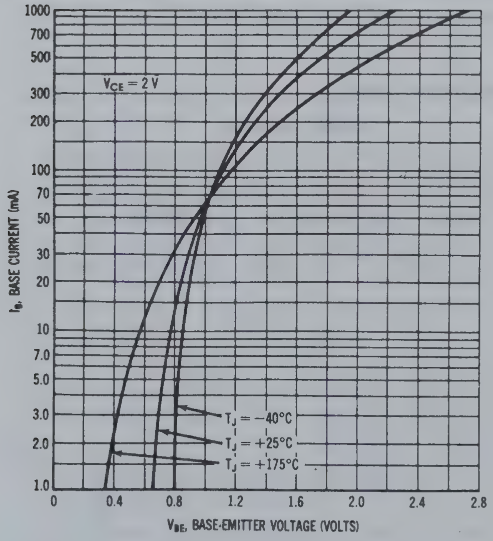


CURRENT GAIN *

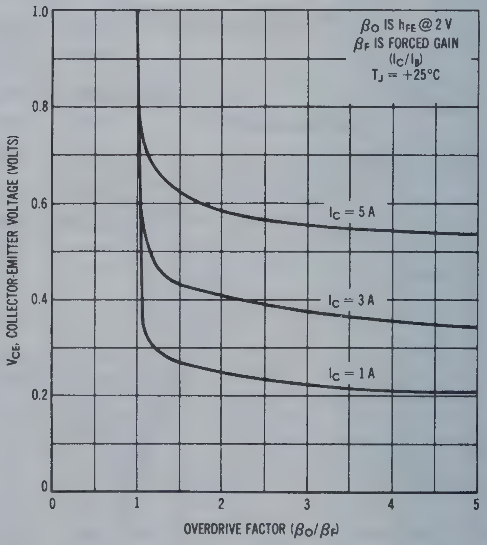


*Dashed line indicates metered base current minus I_{CBO} of the transistor at 175°C.

INPUT ADMITTANCE



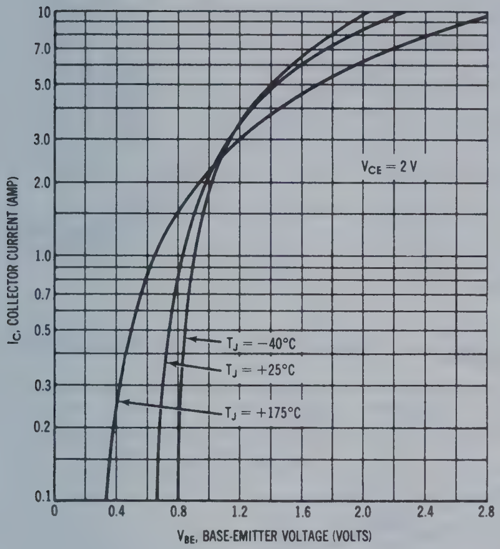
SATURATION REGION



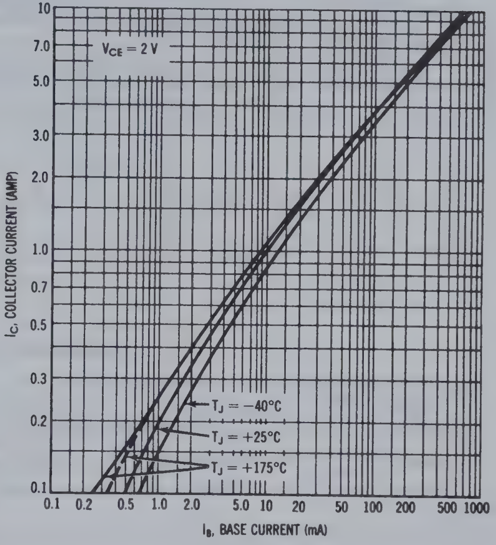
LARGE SIGNAL CHARACTERISTICS – TYPE 2N3791, 2N3792

(PULSE TEST: pulse width ≈ 200 μsec, duty cycle ≈ 1%)

TRANSCONDUCTANCE

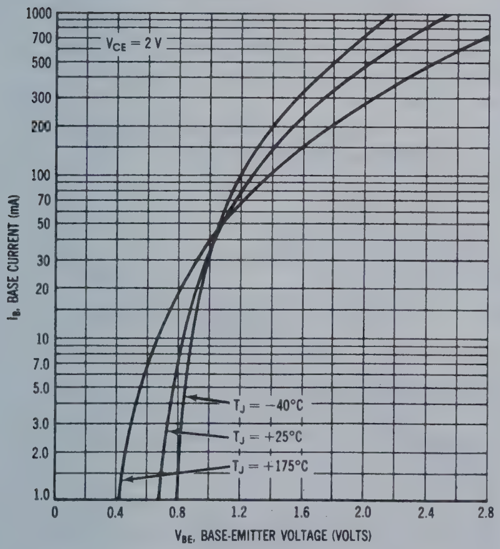


CURRENT GAIN

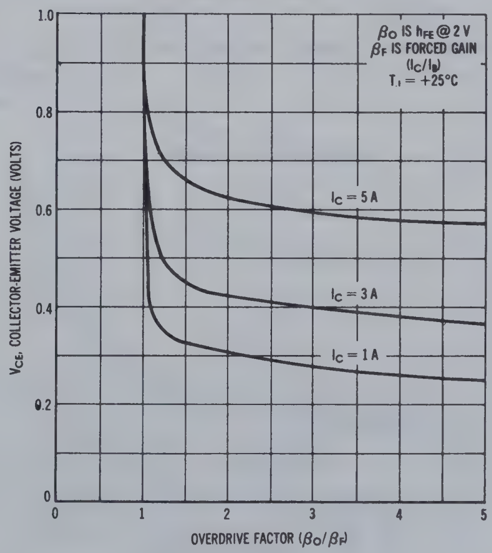


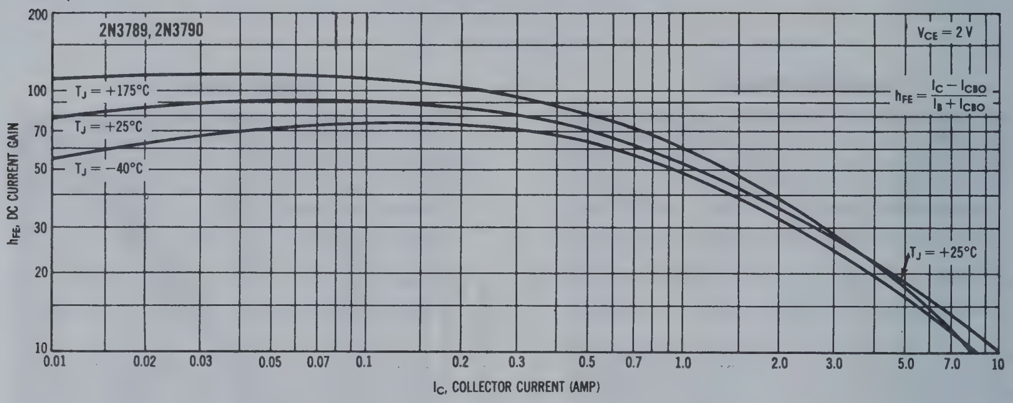
Dashed line indicates metered base current minus I_{CBO} of the transistor at 175°C.

INPUT ADMITTANCE

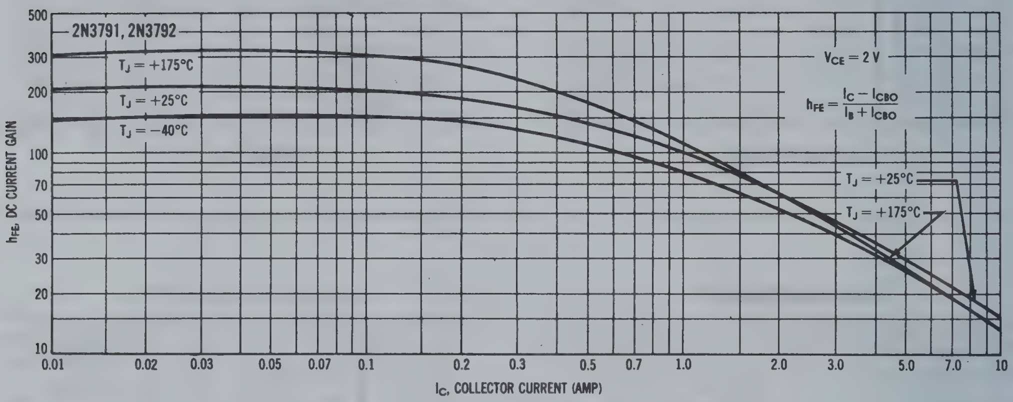


SATURATION REGION

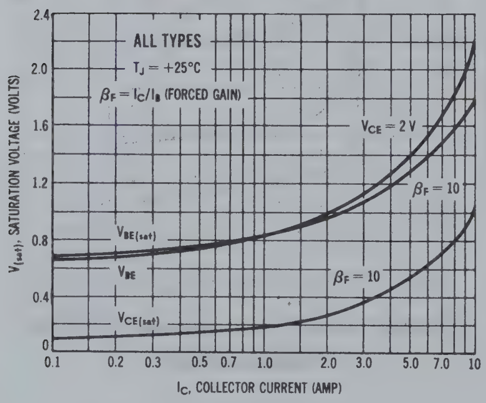




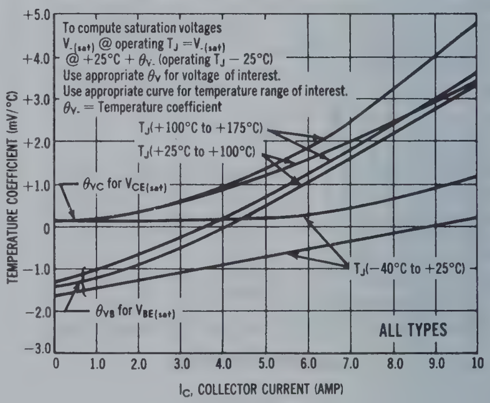
CURRENT GAIN VARIATIONS



CURRENT GAIN VARIATIONS



SATURATION VOLTAGES



TEMPERATURE COEFFICIENTS

To compute saturation voltages
$V_{\cdot(sat)}$ @ operating $T_J = V_{\cdot(sat)}$
@ +25°C + $\theta_{V\cdot}$ (operating T_J − 25°C)
Use appropriate θ_V for voltage of interest.
Use appropriate curve for temperature range of interest.
$\theta_{V\cdot}$ = Temperature coefficient

2N3796 (SILICON)
2N3797

CASE 22 (2)
(TO-18)

Silicon N-channel MOS field-effect transistor designed for low-power applications in the audio frequency range.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage 2N3796 2N3797	V_{DS}	 25 20	Vdc
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	20	mAdc
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Drain-Source Breakdown Voltage		BV_{DSX}				Vdc
(V_{GS} = -4.0 V, I_D = 5.0 μA)	2N3796		25	30	—	
(V_{GS} = -7.0 V, I_D = 5.0 μA)	2N3797		20	25	—	
Zero-Gate-Voltage Drain Current		I_{DSS}				mAdc
(V_{DS} = 10 V, V_{GS} = 0)	2N3796		0.5	1.5	3.0	
	2N3797		2.0	2.9	6.0	
Gate-Source Voltage Cutoff		$V_{GS(off)}$				Vdc
(I_D = 0.5 μA, V_{DS} = 10 V)	2N3796		—	3.0	4.0	
(I_D = 2.0 μA, V_{DS} = 10 V)	2N3797		—	5.0	7.0	
"On" Drain Current		$I_{D(on)}$				mAdc
(V_{DS} = 10 V, V_{GS} = +3.5 V)	2N3796		7.0	8.3	14	
	2N3797		9.0	14	18	
Drain-Gate Reverse Current *		I_{DGO} *				pAdc
(V_{DG} = 10 V, I_S = 0)			—	—	1.0	
Gate-Reverse Current *		I_{GSS} *				pAdc
(V_{GS} = -10 V, V_{DS} = 0)			—	—	1.0	
(V_{GS} = -10 V, V_{DS} = 0, T_A = 150°C)			—	—	200	
Small-Signal, Common-Source Forward Transfer Admittance		$\|y_{fs}\|$				μmhos
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz)	2N3796		900	1200	1800	
	2N3797		1500	2300	3000	
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)	2N3796		900	—	—	
	2N3797		1500	—	—	
Small-Signal, Common-Source, Output Admittance		$\|y_{os}\|$				μmhos
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz)	2N3796		—	12	25	
	2N3797		—	27	60	
Small-Signal, Common-Source, Input Capacitance		C_{iss}				pF
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)	2N3796		—	5.0	7.0	
	2N3797		—	6.0	8.0	
Small-Signal, Common-Source, Reverse Transfer Capacitance		C_{rss}				pF
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)			—	0.5	0.8	
Noise Figure		NF				dB
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz, R_S = 3 megohms)			—	3.8	—	

* This value of current includes both the FET leakage current as well as the leakage current associated with the test socket and fixture when measured under best attainable conditions.

TYPICAL DRAIN CHARACTERISTICS

FIGURE 1 — 2N3796

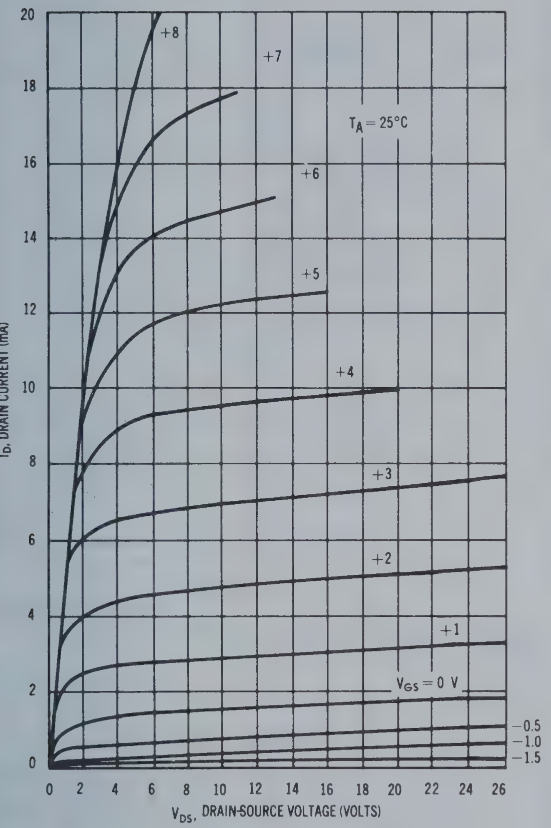
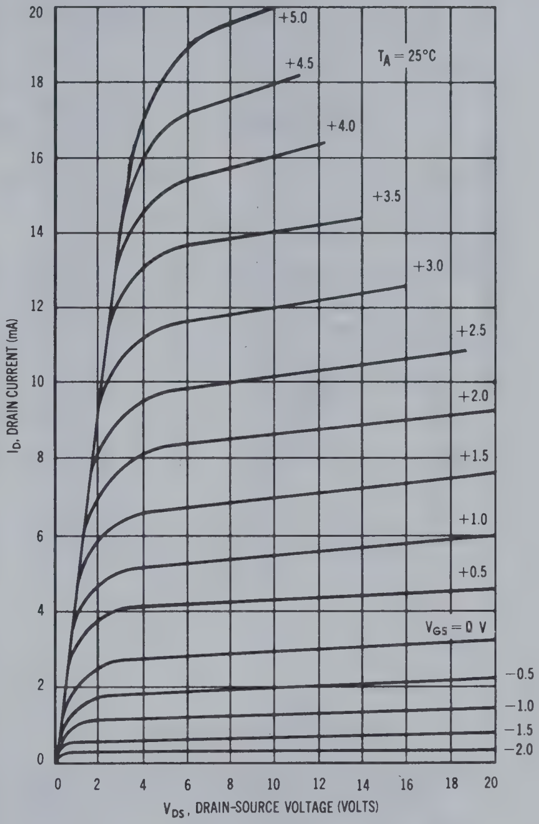


FIGURE 2 — 2N3797



COMMON SOURCE TRANSFER CHARACTERISTICS

FIGURE 3 — 2N3796

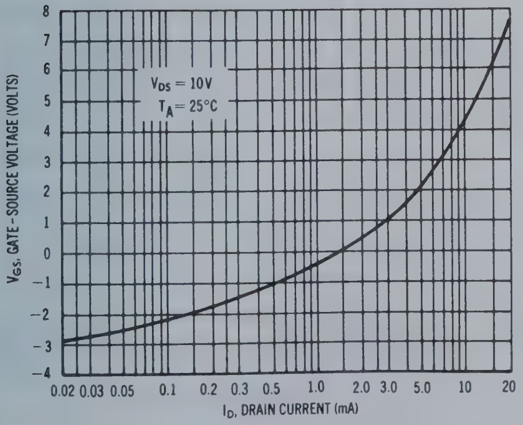


FIGURE 4 — 2N3797

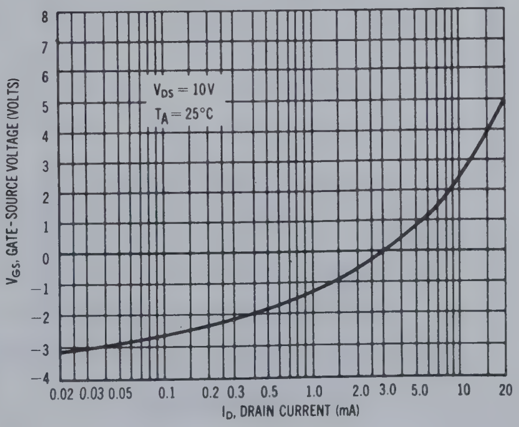


FIGURE 5 — FORWARD TRANSFER ADMITTANCE

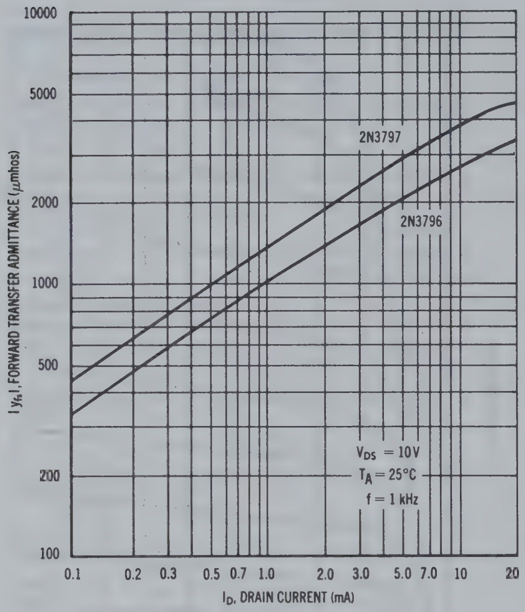


FIGURE 6 — AMPLIFICATION FACTOR

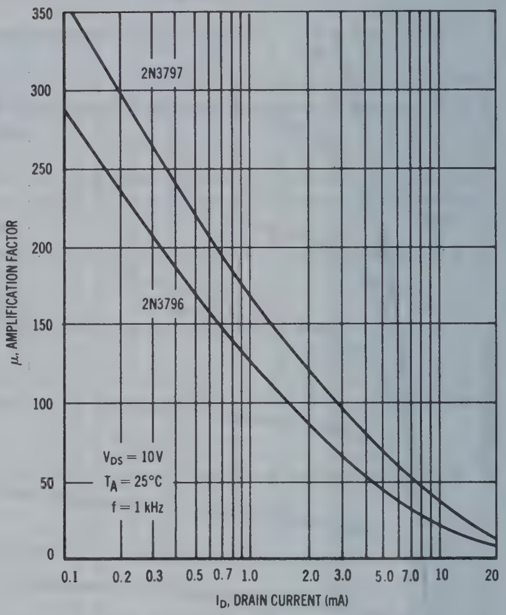


FIGURE 7 — OUTPUT ADMITTANCE

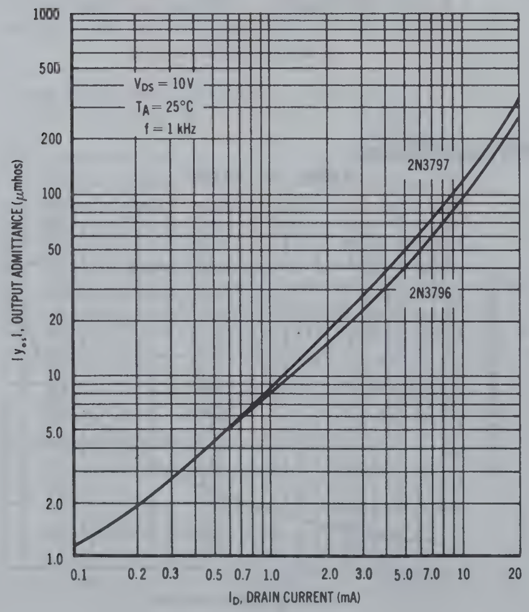
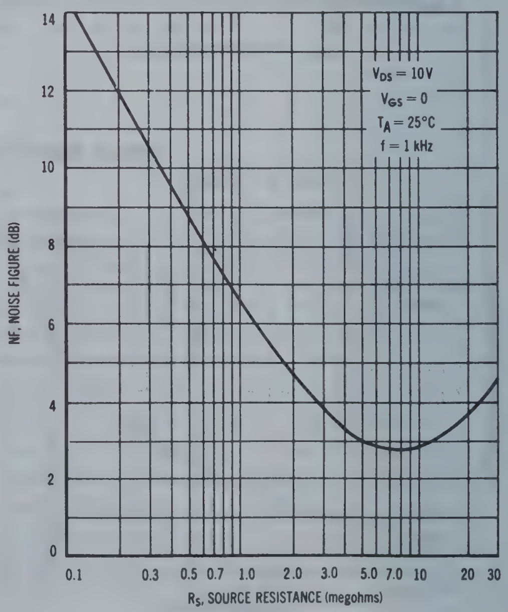


FIGURE 8 — NOISE FIGURE



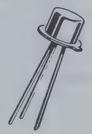
2N3798, 2N3798A (SILICON)
2N3799, 2N3799A

PNP SILICON ANNULAR TRANSISTORS

. . . designed for low-level, low-noise amplifier applications.

- High Collector-Emitter Breakdown Voltages –
  BV_{CEO} = 60 Vdc (Min) – 2N3798, 2N3799
  90 Vdc (Min) – 2N3798A, 2N3799A
- DC Current Gain – @ I_C = 500 μAdc
  h_{FE} = 150-450 – 2N3798, 2N3798A
  300-900 – 2N3799, 2N3799A
- Low Noise Figure –
  NF = 1.5 dB (Max) @ 1.0 kHz and 10 kHz

PNP SILICON AMPLIFIER TRANSISTORS



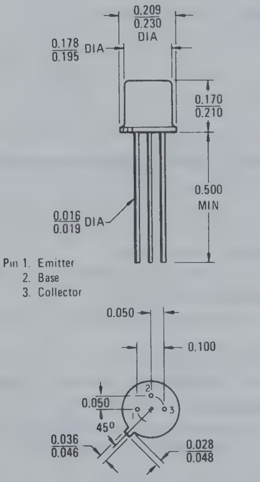
*MAXIMUM RATINGS

Rating	Symbol	2N3798 2N3799	2N3798A 2N3799A	Unit
Collector-Emitter Voltage	V_{CEO}	60	90	Vdc
Collector-Base Voltage	V_{CB}	60	90	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current – Continuous	I_C	50		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.06		Watt W/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.9		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.15	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.49	°C/mW

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
Pin 1. Emitter
2. Base
3. Collector
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

Collector Connected to Case
CASE 22 (1)
(TO-18)

2N3798, 2N3798A, 2N3799, 2N3799A (continued)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage		BV_{CEO}				Vdc
(I_C = 10 mAdc, I_B = 0)	2N3798,2N3799		60	–	–	
	2N3798A,2N3799A		90	–	–	
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 10 μAdc, I_E = 0)	2N3798,2N3799		60	–	–	
	2N3798A,2N3799A		90	–	–	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	–	–	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 50 Vdc, I_E = 0)			–	–	0.01	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)			–	–	10	
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)		I_{EBO}	–	–	20	nAdc
ON CHARACTERISTICS						
DC Current Gain(1)		h_{FE}				–
(I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)	2N3799,2N3799A		75	–	–	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N3798,2N3798A		100	–	–	
	2N3799,2N3799A		225	–	–	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N3798,2N3798A		150	–	–	
	2N3799,2N3799A		300	–	–	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = –55°C)	2N3798,2N3798A		75	–	–	
	2N3799,2N3799A		150	–	–	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc)	2N3798,2N3798A		150	–	450	
	2N3799,2N3799A		300	–	900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N3798,2N3798A		150	–	–	
	2N3799,2N3799A		300	–	–	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	2N3798,2N3798A		125	–	–	
	2N3799,2N3799A		250	–	–	
Collector-Emitter Saturation Voltage(1)		$V_{CE(sat)}$				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)			–	–	0.2	
(I_C = 1.0 mAdc, I_B = 100 μAdc)			–	–	0.25	
Base-Emitter Saturation Voltage(1)		$V_{BE(sat)}$				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)			–	–	0.7	
(I_C = 1.0 mAdc, I_B = 100 μAdc)			–	–	0.8	
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	–	–	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product(2)		f_T				MHz
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)			30	–	–	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)			100	–	500	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	–	–	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	–	–	8.0	pF
Input Impedance		h_{ie}				k ohms
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3798,2N3798A		3.0	–	15	
	2N3799,2N3799A		10	–	40	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{re}	–	–	25	X 10^{-4}
Small-Signal Current Gain		h_{fe}				–
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3798,2N3798A		150	–	600	
	2N3799,2N3799A		300	–	900	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	5.0	–	60	μmhos
Noise Figure		NF				dB
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_G = 3.0 k ohms),						
Spot Noise: f = 100 Hz, B.W. = 20 Hz	2N3798,2N3798A		–	4.0	7.0	
	2N3799,2N3799A		–	2.5	4.0	
Spot Noise: f = 1.0 kHz, B.W. = 200 Hz	2N3798,2N3798A		–	1.5	3.0	
	2N3799,2N3799A		–	0.8	1.5	
Spot Noise: f = 10 kHz, B.W. = 2.0 kHz	2N3798,2N3798A		–	1.0	2.5	
	2N3799,2N3799A		–	0.8	1.5	
Broadband Noise-Bandwidth 10 Hz to 15.7 kHz	2N3798,2N3798A		–	2.5	3.5	
	2N3799,2N3799A		–	1.5	2.5	

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤300 μs, Duty Cycle ≤2.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

SPOT NOISE FIGURE

(V_{CE} = 10 Vdc, T_A = 25°C)

FIGURE 1 – SOURCE RESISTANCE EFFECTS, f = 1.0 kHz

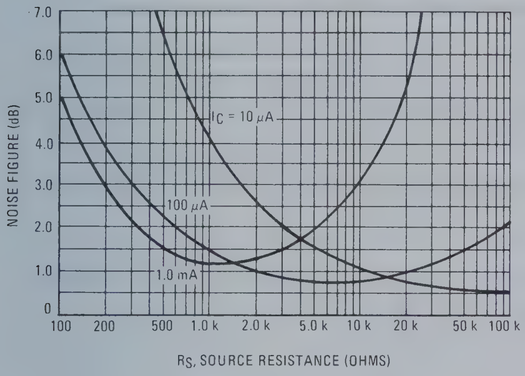


FIGURE 2 – SOURCE RESISTANCE EFFECTS, f = 10 Hz

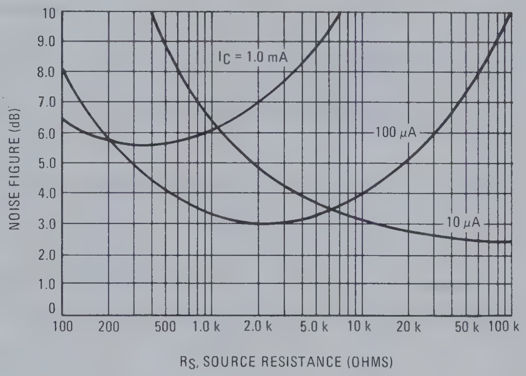


FIGURE 3 – FREQUENCY EFFECTS

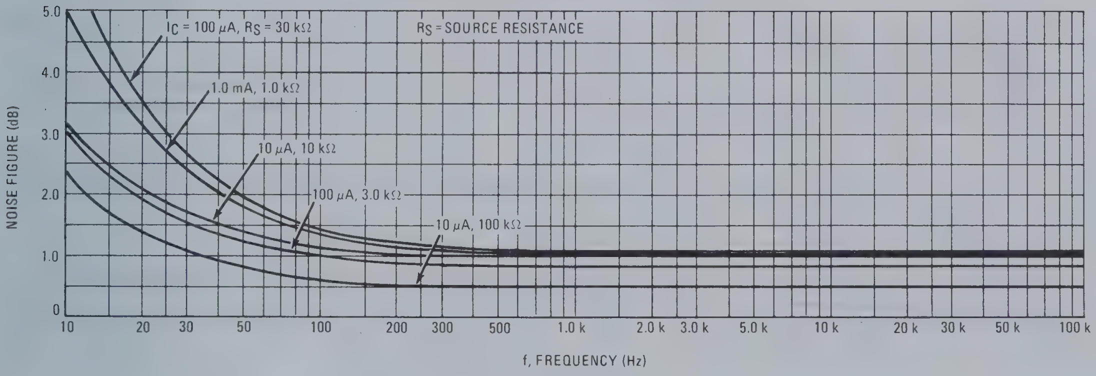
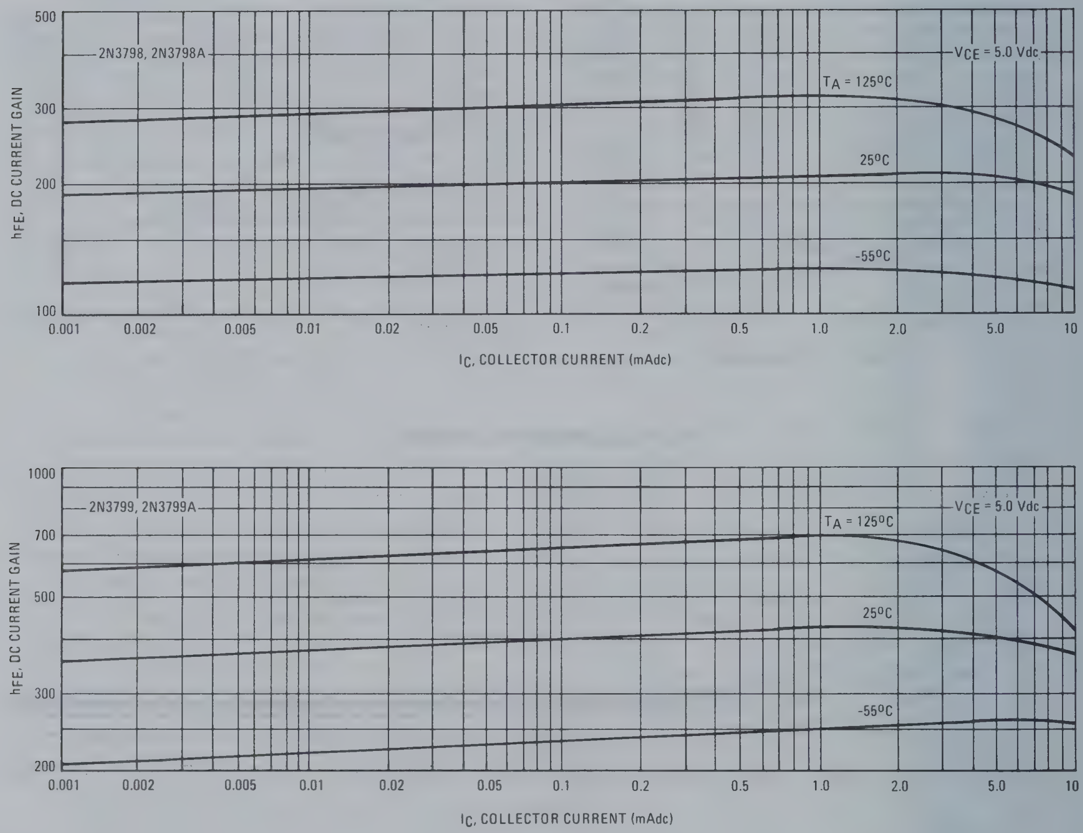


FIGURE 4 – TYPICAL CURRENT GAIN CHARACTERISTICS



2N3800 thru 2N3804,A (SILICON)
2N3805,A, 2N3806
thru
2N3810,A, 2N3811,A
2N3812 thru 2N3816,A, 2N3817,A

DUAL PNP SILICON ANNULAR TRANSISTORS

. . . specifically designed for differential amplifier applications.

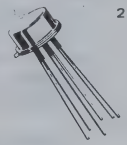
- Tight h_{FE} Match: 5%
- High h_{FE}: to 225 (min) @ $I_C = 10\ \mu$Adc
- Low Noise: 1.5 dB (Max) @ 1.0 kHz and 10 kHz
- h_{FE} Match Temperature Tracking: from − 55°C to +125°C
- Tight V_{BE} Match: 1.5 mVdc
- 2N3810 JAN, JTX and 2N3811 JAN, JTX Available

PNP SILICON
DIFFERENTIAL
AMPLIFIERS

***MAXIMUM RATINGS** (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25°C$	P_D			
Metal Can (2N3800 thru 2N3804,A 2N3805,A		250	360	mW
Derate above 25°C		1.43	2.06	mW/°C
Metal Can (2N3806 thru 2N3810,A, 2N3811,A		500	600	mW
Derate above 25°C		2.86	3.43	mW/°C
Flat Package (2N3812 thru 2N3816,A, 2N3817,A		250	250	mW
Derate above 25°C		1.43	2.06	mW/°C

*Indicates JEDEC Registered Data.

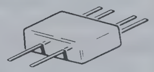


2N3800 thru 2N3804,A
2N3805,A

Case
655

2N3806 thru 2N3810,A
2N3811,A

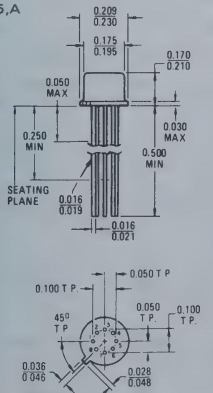
Case
654-04



2N3812 thru 2N3816,A
2N3817,A

Case 610A-03

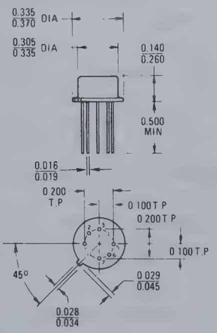
2N3800 thru 2N3804,A
2N3805,A


0.209
0.230
0.175
0.195
0.170
0.210
0.050
MAX
0.250
MIN
0.030
MAX
0.500
MIN
SEATING
PLANE
0.016
0.019
0.016
0.021
0.050 T P
0.100 T P.
0.050
T P.
0.100
T P.
45°
T P
1
2
3
4
5
6
7
8
0.036
0 046
0.028
0.048

Case
655

Pins 4 and 8 omitted
All JEDEC dimensions and notes apply

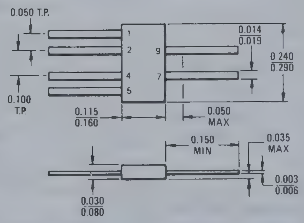
2N3806 thru 2N3810,A
2N3811,A


0.335
0.370
DIA
0.305
0 335
DIA
0.140
0.260
0.500
MIN
0.016
0.019
0 200
T.P
0 100 T P
0 200 T P
0 100 T.P
2
3
5
6
7
45°
0 029
0.045
0.028
0.034

Case
654-04

All Leads Electrically Isolated from Case

2N3812 thru 2N3816,A
2N3817,A


0.050 T.P.
1
2
4
5
9
7
0.014
0.019
0 240
0.290
0.100
T.P.
0.115
0.160
0.050
MAX
0.150
MIN
0.035
MAX
0.003
0.006
0.030
0.080

Case 610A-03

***ELECTRICAL CHARACTERISTICS** (each side) ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	60	–	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0)		–	0.01	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)		–	10	
Emitter Cutoff Current ($V_{BE(off)}$= 4.0 Vdc, I_C = 0)	I_{EBO}	–	20	nAdc
ON CHARACTERISTICS				
DC Current Gain (1)	h_{FE}			–
(I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc) 2N3801,3,5,A,7,9,11,A,13,15,17,A		75	–	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N3800,2,4,A,6,8,10,A,12,14,16,A		100	–	
2N3801,3,5,A,7,9,11,A,13,15,17,A		225	–	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3800,2,4,A,6,8,10,A,12,14,16,A		150	450	
2N3801,3,5,A,7,9,11,A,13,15,17,A		300	900	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = –55°C) 2N3800,2,4,A,6,8,10,A,12,14,16,A		75	–	
2N3801,3,5,A,7,9,11,A,13,15,17,A		150	–	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc) 2N3800,2,4,A,6,8,10,A,12,14,16,A		150	450	
2N3801,3,5,A,7,9,11,A,13,15,17,A		300	900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N3800,2,4,A,6,8,10,A,12,14,16,A		150	450	
2N3801,3,5,A,7,9,11,A,13,15,17,A		300	900	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N3800,2,4,A,6,8,10,A,12,14,16,A		125	–	
2N3801,3,5,A,7,9,11,A,13,15,17,A		250	–	
Collector-Emitter Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		–	0.2	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		–	0.25	
Base-Emitter Saturation Voltage (1)	$V_{BE(sat)}$			Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		–	0.7	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		–	0.8	
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	–	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current Gain – Bandwidth Product	f_T			MHz
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)		30	–	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)		100	500	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	–	4.0	pF
Input Capacitance ($V_{BE(off)}$ = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	–	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}			kΩ
2N3800,2,4,A,6,8,10,A,12,14,16,A		3.0	15	
2N3801,3,5,A,7,9,11,A,13,15,17,A		10	40	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	–	25	$X 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}			–
2N3800,2,4,A,6,8,10,A,12,14,16,A		150	600	
2N3801,3,5,A,7,9,11,A,13,15,17,A		300	900	

2N3800 thru 2N3804,A, 2N3805,A, 2N3806 thru 2N3810,A, 2N3811,A, 2N3812 thru 2N3816,A, 2N3817,A (continued)

Characteristic	Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS (continued)				
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	5.0	60	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_G = 3.0 k ohms)	NF			dB
Spot Noise f = 100 Hz, BW = 20 Hz 2N3800, 2,4,A,6,8,10,A,12,14,16,A		–	7.0	
2N3801,3,5,A,7,9,11,A,13,15,17,A		–	4.0	
f = 1.0 kHz, BW = 2.0 kHz 2N3800,2,4,A,6,8,10,A,12,14,16,A		–	3.0	
2N3801,3,5,A,7,9,11,A,13,15,17,A		–	1.5	
f = 10 kHz, BW = 200 Hz 2N3800,2,4,A,6,8,10,A,12,14,16,A		–	2.5	
2N3801,3,5,A,7,9,11,A,13,15,17,A		–	1.5	
Broadband Noise Bandwidth 10 Hz to 15.7 kHz 2N3800,2,4,A,6,8,10,A,12,14,16,A		–	3.5	
2N3801,3,5,A,7,9,11,A,13,15,17,A		–	2.5	
MATCHING CHARACTERISTICS				
DC Current Gain Ratio (2) (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3802,3,8,9,14,15	h_{FE1}/h_{FE2}	0.8	1.0	–
2N3804,5,10,11,16,17		0.9	1.0	
2N3804A,5A,10A,11A,16A,17A		0.95	1.0	
(I_C = 100 μAdc, V_{CE} = 50 Vdc, T_A = −55 to +125°C) 2N3804A,5A,10A,11A,16A,17A		0.85	1.0	
Base Voltage Differential (I_C = 10 μAdc to 10 mAdc, V_{CE} = 5.0 Vdc) 2N3802,3,8,9,14,15	$\lvert V_{BE1}-V_{BE2}\rvert$	–	8.0	mVdc
2N3804,A,5,A,10,A,11,A,16,A,17,A		–	5.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3802,3,8,9,14,15		–	5.0	
2N3804,5,10,11,16,17		–	3.0	
2N3804A,5A,10A,11A,16A,17A		–	1.5	
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = −55 to +25°C) 2N3802,3,8,9,14,15	$\Delta\lvert V_{BE1}-V_{BE2}\rvert$	–	1.6	mVdc
2N3804,5,10,11,16,17		–	0.8	
2N3804A,5A,10A,11A,16A,17A		–	0.4	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C) 2N3802,3,8,9,14,15		–	2.0	
2N3804,5,10,11,16,17		–	1.0	
2N3804A,5A,10A,11A,16A,17A		–	0.5	

*Indicates JEDEC Registered Data.

(1) Pulse Test: Pulse Width ≤300 μs, Duty Cycle ≤2.0%.

(2) The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

SPOT NOISE FIGURE (V_{CE} = 10 Vdc, T_A = 25°C)

FIGURE 1 – SOURCE RESISTANCE EFFECTS, f = 1.0 kHz

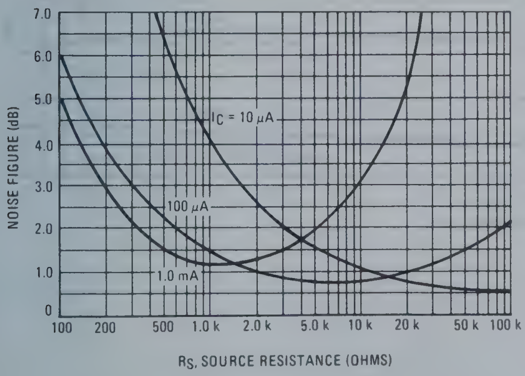
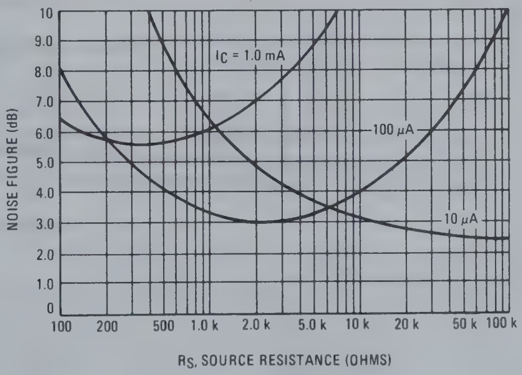


FIGURE 2 – SOURCE RESISTANCE EFFECTS, f = 10 Hz



2N3800 thru 2N3804,A, 2N3805,A, 2N3806 thru 2N3810,A, 2N3811,A, 2N3812 thru 2N3816,A, 2N3817,A (continued)

FIGURE 3 – SPOT NOISE FIGURE
FREQUENCY EFFECTS

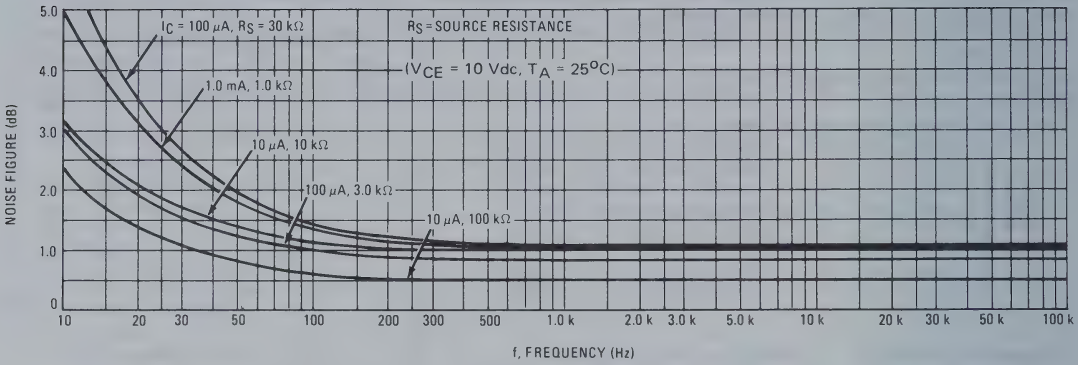


FIGURE 4 – TYPICAL CURRENT GAIN CHARACTERISTICS
(TYPES 2N3800,2,4,A,6,8,10,A,12,14,16,A)

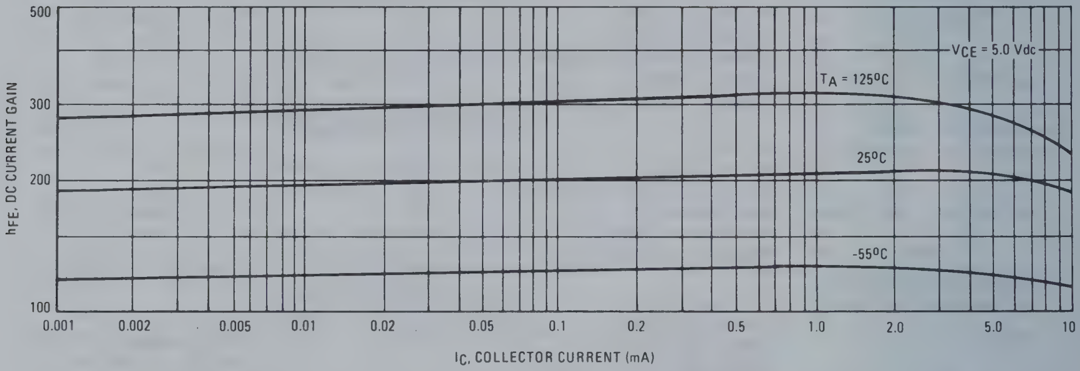
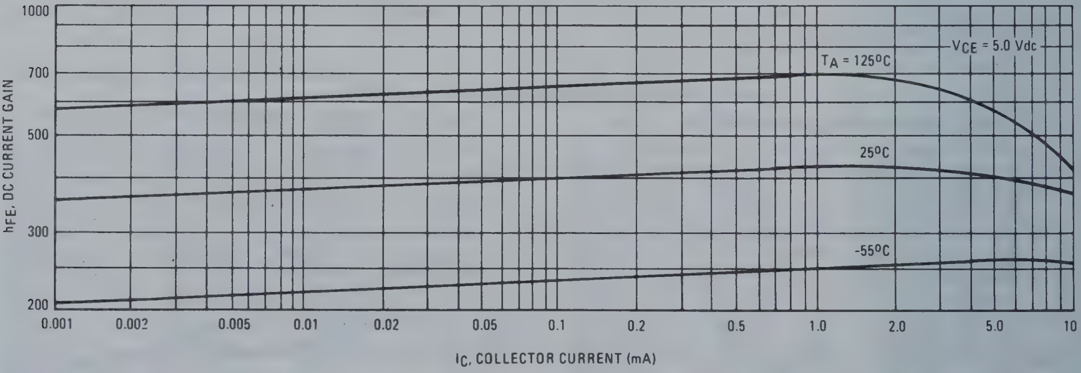


FIGURE 5 – TYPICAL CURRENT GAIN CHARACTERISTICS
(TYPES 2N3801,3,5,A,7,9,11,A,13,15,17,A)



2N3818 (SILICON)

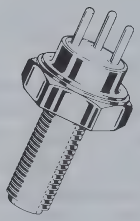
The RF Line

15 W – 100 MHz
RF POWER
TRANSISTOR
NPN SILICON

NPN SILICON RF POWER TRANSISTOR

. . . designed for applications to 150 MHz.

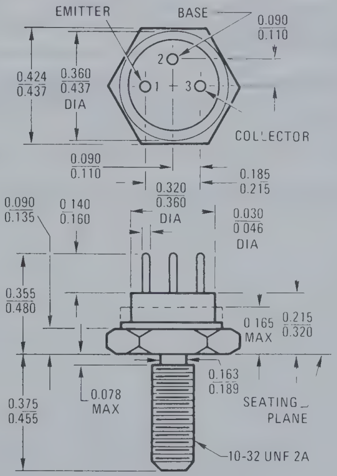
- High Collector-Emitter Sustaining Voltage –
  $V_{CE(sus)}$ = 80 Vdc (Min)
- Power Output –
  P_{out} = 15 Watts at 100 MHz
- Power Gain –
  G_{PE} = 7.0 dB (Typ) at 100 MHz with 15 Watts RF Power Output



MAXIMUM RATINGS (Note 1)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	60	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current – Continuous	I_C	2.0	Adc
Base Current – Continuous	I_B	1.0	mAdc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	25 167	Watts mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	^oC
Power Input (Nominal)	P_{in}	5.0	Watts
Power Output (Nominal)	P_{out}	20	Watts

Note 1. The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See electrical characteristics.


EMITTER
BASE
0.090
0.110
2
1
3
0.424
0.437
0.360
0.437
DIA
COLLECTOR
0.090
0.110
0.185
0.215
0.320
0.360
DIA
0.090
0.135
0.140
0.160
0.030
0.046
DIA
0.355
0.480
0.165
MAX
0.215
0.320
0.163
0.189
0.078
MAX
0.375
0.455
SEATING PLANE
10-32 UNF 2A

To convert inches to millimeters multiply by 25.4

All JEDEC dimensions and notes apply

STYLE 1. All leads isolated from case

CASE 36
TO-60

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage(1) (I_C = 0.25 Adc, I_B = 0)	$V_{CEO(sus)}$	40	–	–	Vdc
Collector-Emitter Sustaining Voltage(1) (I_C = 0.25 Adc, R_{BE} = 0)	$V_{CES(sus)}$	80	100	–	Vdc
Collector-Emitter Current	I_{CES}				mAdc
(V_{CE} = 60 Vdc, V_{BE} = 0)		–	–	0.5	
(V_{CE} = 50 Vdc, V_{BE} = 0, T_C = 175°C)		–	–	1.0	
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	I_{CBO}	–	–	1.0	μAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	–	–	100	μAdc
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				–
(I_C = 400 mAdc, V_{CE} = 2.0 Vdc)		5.0	–	50	
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)		5.0	–	–	
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 250 mAdc)	$V_{CE(sat)}$	–	–	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 250 mAdc)	$V_{BE(sat)}$	–	–	2.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (V_{CE} = 2.0 Vdc, I_C = 400 mAdc, f = 50 MHz)	f_T	150	–	–	MHz
Output Capacitance (V_{CB} = 25 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	–	–	40	pF

FUNCTIONAL TEST

Power Input	Test Circuit Figure 5 (P_{out} = 15 W, f = 100 MHz, V_{CE} = 25 Vdc, I_C(max) = 1.0 Adc)	P_{in}	–	3.0	3.75	Watts
Efficiency		η	60	70	–	%

(1)Pulse Test: Pulse Width ≤100 μs, Duty Cycle = 2.0%.

FIGURE 1 – OUTPUT POWER versus FREQUENCY

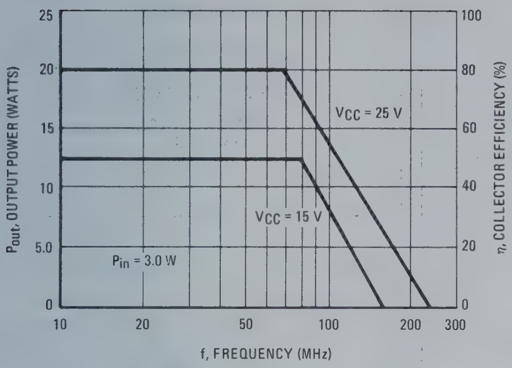


FIGURE 2 – OUTPUT CHARACTERISTICS versus INPUT POWER

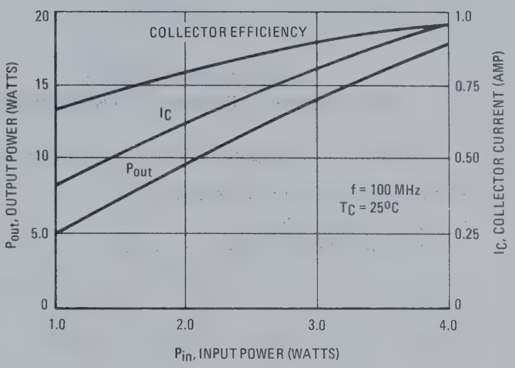


FIGURE 3 – OUTPUT POWER versus COLLECTOR VOLTAGE

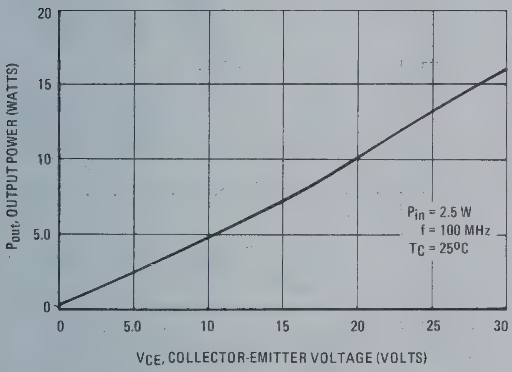


FIGURE 4 – OUTPUT POWER versus INPUT POWER

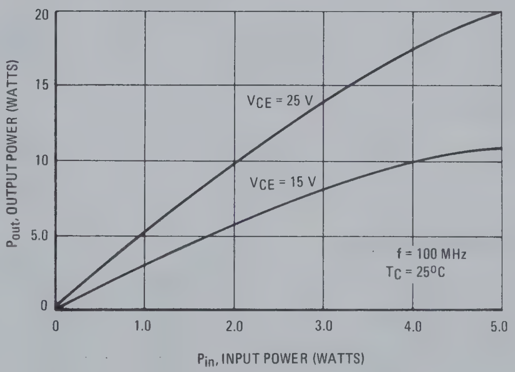
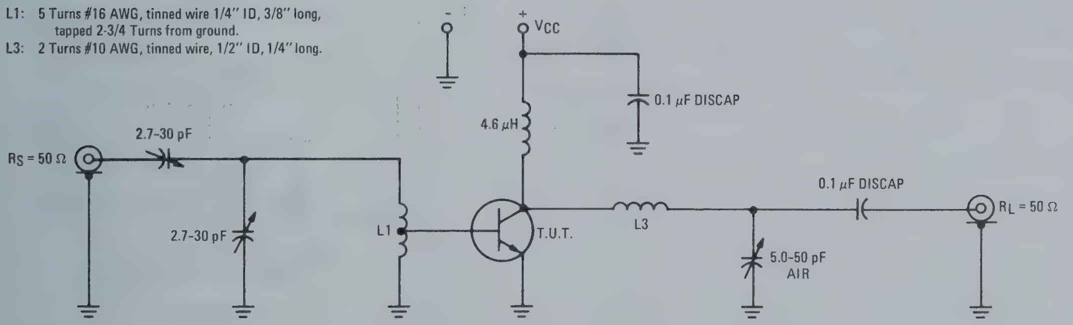


FIGURE 5 – TEST CIRCUIT

L1: 5 Turns #16 AWG, tinned wire 1/4" ID, 3/8" long, tapped 2-3/4 Turns from ground.

L3: 2 Turns #10 AWG, tinned wire, 1/2" ID, 1/4" long.


-
+
V_{CC}
0.1 μF DISCAP
4.6 μH
R_S = 50 Ω
2.7-30 pF
2.7-30 pF
L1
T.U.T.
L3
0.1 μF DISCAP
5.0-50 pF
AIR
R_L = 50 Ω

2N3821 (SILICON)
2N3822
2N3824

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

. . . designed for audio amplifier, chopper and switching applications.

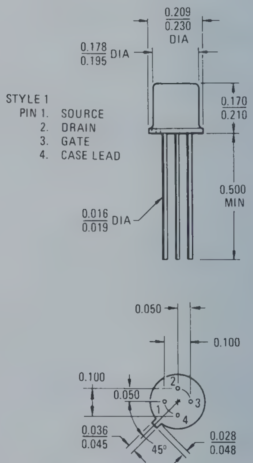
- Drain and Source Interchangeable
- Low Drain-Source Resistance —
  $r_{ds(on)} \leqslant 250$ Ohms (Max) — 2N3824
- Low Noise Figure — NF = 5.0 dB (Max) — 2N3821, 2N3822
- High AC Input Impedance — C_{iss} = 6.0 pF (Max)
- High DC Input Resistance — I_{GSS} = 0.1 nA (Max)
- Low Transfer Capacitance — C_{rss} = 3.0 pF (Max)
- 2N3821 JAN and 2N3822 JAN also Available

N-CHANNEL
JUNCTION
FIELD-EFFECT
TRANSISTORS
SYMMETRICAL
(Type A)

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	50	Vdc
Drain-Gate Voltage	V_{DG}	50	Vdc
Gate-Source Voltage	V_{GS}	-50	Vdc
Drain Current	I_D	10	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 2.0	mW mW/^oC
Operating Junction Temperature	T_J	175	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195 DIA
STYLE 1
PIN 1. SOURCE
2. DRAIN
3. GATE
4. CASE LEAD
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
0.100
0.100
0.050
1
2
3
4
0.036
0.045
45°
0.028
0.048

To convert inches to millimeters multiply by 25.4

All JEDEC dimensions and notes apply

CASE 20
TO-72

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = −1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	−50	—	Vdc
Gate Reverse Current		I_{GSS}			nAdc
(V_{GS} = −30 Vdc, V_{DS} = 0)			—	−0.1	
(V_{GS} = −30 Vdc, V_{DS} = 0, T_A = 150°C)			—	−100	
Gate-Source Cutoff Voltage		$V_{GS(off)}$			Vdc
(I_D = 0.5 nAdc, V_{DS} = 15 Vdc)	2N3821		—	−4.0	
	2N3822		—	−6.0	
Gate-Source Voltage		V_{GS}			Vdc
(I_D = 50 μAdc, V_{DS} = 15 Vdc)	2N3821		−0.5	−2.0	
(I_D = 200 μAdc, V_{DS} = 15 Vdc)	2N3822		−1.0	−4.0	
Drain Cutoff Current		$I_{D(off)}$			nAdc
(V_{DS} = 15 Vdc, V_{GS} = −8.0 Vdc)	2N3824		—	0.1	
(V_{DS} = 15 Vdc, V_{GS} = −8.0 Vdc, T_A = 150°C)	2N3824		—	100	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current(1)		I_{DSS}			mAdc
(V_{DS} = 15 Vdc, V_{GS} = 0)	2N3821		0.5	2.5	
	2N3822		2.0	10	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance		$\lvert y_{fs} \rvert$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)(1)	2N3821		1500	4500	
	2N3822		3000	6500	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	2N3821		1500	—	
	2N3822		3000	—	
Output Admittance(1)		$\lvert y_{os} \rvert$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N3821		—	10	
	2N3822		—	20	
Drain-Source Resistance		$r_{ds(on)}$			Ohms
(V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N3824		—	250	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	—	6.0	pF
Reverse Transfer Capacitance		C_{rss}			pF
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	2N3821		—	3.0	
	2N3822		—	3.0	
(V_{GS} = −8.0 Vdc, V_{DS} = 0, f = 1.0 MHz)	2N3824		—	3.0	
Average Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1.0 megohm, f = 10 Hz, Noise Bandwidth = 5.0 Hz)	2N3821, 2N3822	NF	—	5.0	dB
Equivalent Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 10 Hz, Noise Bandwidth = 5.0 Hz)	2N3821, 2N3822	e_n	—	200	nv/Hz$^{1/2}$

*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width ≤ 100 ms, Duty Cycle ≤ 10%.

2N3823 (SILICON)

N-CHANNEL
JUNCTION
FIELD-EFFECT
TRANSISTOR
SYMMETRICAL
(Type A)

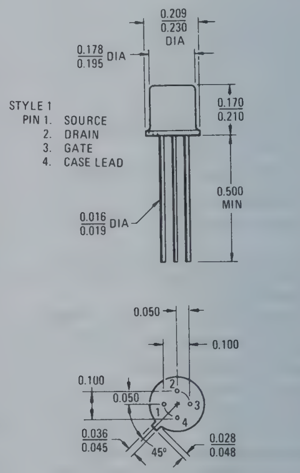
SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

. . . designed for VHF amplifier and mixer applications.

- Low Cross-Modulation and Intermodulation Distortion
- Drain and Source Interchangeable
- Low 100-MHz Noise Figure — 2.5 dB (Max)
- Low Transfer and Input Capacitances —
  C_{rss} = 2.0 pF (Max)
  C_{iss} = 6.0 pF (Max)
- 2N3823 JAN also Available

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	-30	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
0.100
0.100
0.050
2
3
1
4
0.036
0.045
45°
0.028
0.048

STYLE 1
PIN 1. SOURCE
2. DRAIN
3. GATE
4. CASE LEAD

To convert inches to millimeters multiply by 25.4

All JEDEC dimensions and notes apply

CASE 20
TO-72

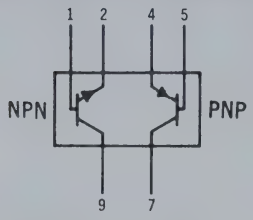
***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = −1.0 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	-30	–	Vdc
Gate Reverse Current (V_{GS} = −20 Vdc, V_{DS} = 0) (V_{GS} = −20 Vdc, V_{DS} = 0, T_A = 150°C)	I_{GSS}	 – –	 -0.5 -500	nAdc
Gate-Source Cutoff Voltage (I_D = 0.5 nAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	–	-8.0	Vdc
Gate-Source Voltage (I_D = 0.4 mAdc, V_{DS} = 15 Vdc)	V_{GS}	-1.0	-7.5	Vdc
ON CHARACTERISTICS				
Zero-Gate-Voltage Drain Current(1) (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}	4.0	20	mAdc
DYNAMIC CHARACTERISTICS				
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)(1) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$\lvert y_{fs} \rvert$	 3500 3200	 6500 –	μmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$Re(y_{is})$	–	800	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)(1) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	 $\lvert y_{os} \rvert$ $Re(y_{os})$	 – –	 35 200	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	–	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	–	2.0	pF
Common-Source Spot Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1000 ohms, f = 100 MHz)	NF	–	2.5	dB

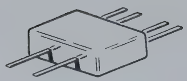
*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 100 ms, Duty Cycle ≤10%.

2N3838 (SILICON)


1
2
4
5
NPN
PNP
9
7

Pin Connections, Bottom View



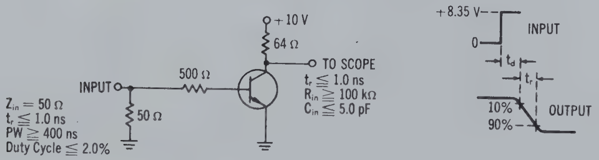
Case 610-02

NPN-PNP complementary pair silicon annular transistor designed for switching and general purpose amplifier applications.

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
		One Side	Both Sides	
Collector-Emitter Voltage (Applicable from 0 to 10 mAdc)	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current — Continuous	I_C	600		mAdc
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
Total Device Dissipation @ $T_A = 25°C$	P_D	0.25	0.35	Watt
Derate above 25°C		1.67	2.34	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	0.7	1.4	Watt
Derate above 25°C		4.67	9.34	mW/°C

FIGURE 1 — TURN-ON TIME TEST CIRCUIT


+10 V
64 Ω
TO SCOPE
$t_r \leq 1.0$ ns
$R_{in} \geq 100$ kΩ
$C_{in} \leq 5.0$ pF
500 Ω
INPUT
50 Ω
$Z_{in} = 50$ Ω
$t_r \leq 1.0$ ns
PW ≧ 400 ns
Duty Cycle ≦ 2.0%
+8.35 V
0
INPUT
t_d
t_r
10%
90%
OUTPUT

(Reverse voltage polarities when testing the PNP unit.)

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT

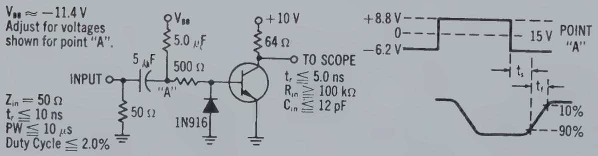
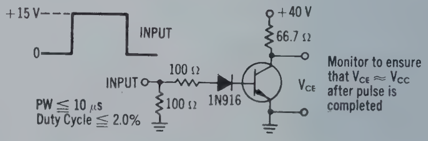

$V_{BB} \approx -11.4$ V
Adjust for voltages shown for point "A".
V_{BB}
5.0 μF
+10 V
64 Ω
5 μF
500 Ω
"A"
INPUT
TO SCOPE
$t_r \leq 5.0$ ns
$R_{in} \geq 100$ kΩ
$C_{in} \leq 12$ pF
$Z_{in} = 50$ Ω
$t_r \leq 10$ ns
PW ≦ 10 μs
Duty Cycle ≦ 2.0%
50 Ω
1N916
+8.8 V
0
−6.2 V
15 V
POINT "A"
t_s
t_f
10%
90%

FIGURE 3 — COLLECTOR-EMITTER NONLATCHING VOLTAGE TEST CIRCUIT


+15 V
0
INPUT
+40 V
66.7 Ω
100 Ω
INPUT
1N916
100 Ω
V_{CE}
PW ≦ 10 μs
Duty Cycle ≦ 2.0%
Monitor to ensure that $V_{CE} \approx V_{CC}$ after pulse is completed

2N3838 (continued)

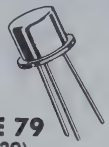
ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Emitter Nonlatching Voltage (Figure 3) † ($I_{C(on)}$ = 600 mAdc, $I_{B(on)}$ = 120 mAdc, $I_{B(off)}$ = 0)	$V_{CEO(NL)}$ †	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc) (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc, T_A = 150°C)	I_{CEV}	 - -	 0.01 10	μAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	10	nAdc
Base Cutoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc)	I_{BEV}	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (1) (I_C = 150 mAdc, V_{CE} = 10 Vdc) (1) (I_C = 150 mAdc, V_{CE} = 1.0 Vdc) (1)	h_{FE}	 35 50 75 100 50	 - - - 300 -	-
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	0.85	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	1.5	9.0	k ohm
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	60	300	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	-	50	μmho
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz)	NF	-	8.0	dB
Delay Time — (V_{CC} = 10 Vdc, $V_{BE(off)}$ = 0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc, Figure 1)	t_d	-	10	ns
Rise Time	t_r	-	40	ns
Storage Time — (V_{CC} = 10 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc, Figure 2)	t_s	-	250	ns
Fall Time	t_f	-	90	ns

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

† The highest value of collector supply voltage that may be safely used with a resistive load switching circuit in which the collector current is 600 mAdc.

2N3866 (SILICON)
2N3866A



CASE 79
(TO-39)

Collector connected to case

NPN silicon transistor, designed for amplifier, frequency-multiplier, or oscillator applications in military and industrial equipment. Suitable for uses as output, driver, or pre-driver stages in VHF and UHF equipment.

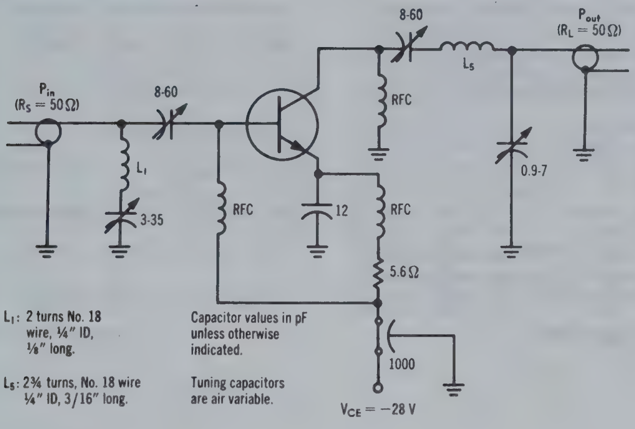
MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	55	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Amp
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 5.0 mAdc, R_{BE} = 10 ohms)	BV_{CER}	55	–	–	Vdc
Collector-Emitter Sustaining Voltage (I_C = 5.0 mAdc, I_B = 0)	$BV_{CEO(sus)}$	30	–	–	Vdc
Collector-Base Breakdown Voltage (I_E = 0, I_C = 0.1 mAdc)	BV_{CBO}	55	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	3.5	–	–	Vdc
Collector Cutoff Current (V_{CE} = 28 Vdc, I_B = 0)	I_{CEO}	–	–	20	µA
Collector Cutoff Current (V_{CE} = 55 Vdc, V_{BE} = 1.5 Vdc)	I_{CEX}	–	–	100	µAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.36 Adc, V_{CE} = 5.0 Vdc) (I_C = 0.05 Adc, V_{CE} = 5.0 Vdc) 2N3866 (I_C = 50 mAdc, V_{CE} = 5.0 Vdc) 2N3866A	h_{FE}	 5.0 10 25	 – – –	 – 200 200	–
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	–	–	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_C = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) 2N3866 2N3866A	f_T	 500 800	 800 –	 – –	MHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	–	2.0	3.0	pF
FUNCTIONAL TEST					
Power Gain — Test Circuit-Figure 1 P_{in} = 0.1 W, V_{CE} = 28 Vdc f = 400 MHz, T_C = 25°C	G_{pe}	10	–	–	dB
Power Output	P_{out}	1.0	–	–	Watts
Collector Efficiency	η	45	–	–	%

FIGURE 1 — 400 MHz RF AMPLIFIER CIRCUIT FOR POWER-OUTPUT TEST


8-60
P_{out}
(R_L = 50 Ω)
L_S
P_{in}
(R_S = 50 Ω)
8-60
RFC
L_1
0.9-7
3-35
RFC
12
RFC
5.6 Ω
1000
V_{CE} = −28 V

L_1: 2 turns No. 18 wire, ¼″ ID, ⅛″ long.

L_S: 2¾ turns, No. 18 wire ¼″ ID, 3/16″ long.

Capacitor values in pF unless otherwise indicated.

Tuning capacitors are air variable.

FIGURE 2 — POWER OUTPUT versus FREQUENCY (Class C)

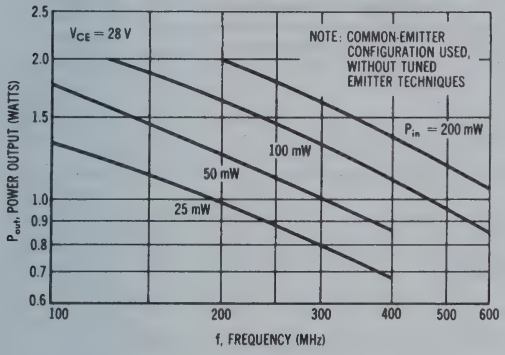


FIGURE 4 — PARALLEL INPUT RESISTANCE AND CAPACITANCE versus FREQUENCY (Class C)

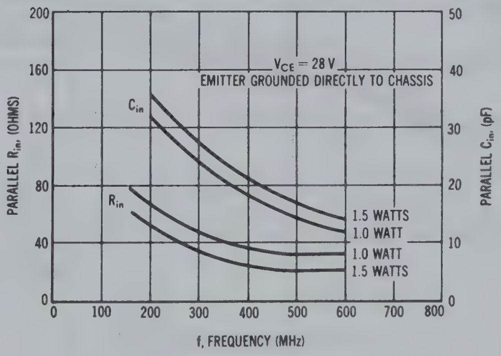


FIGURE 3 — POWER OUTPUT versus POWER INPUT (Class C)

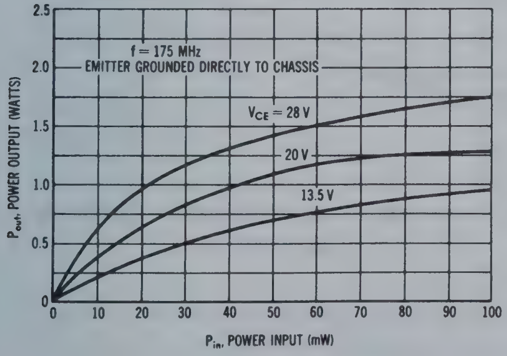


FIGURE 5 — PARALLEL OUTPUT CAPACITANCE versus FREQUENCY (Class C)

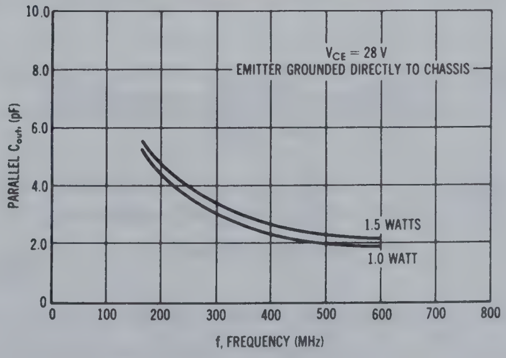


FIGURE 6 — SMALL-SIGNAL CURRENT GAIN versus FREQUENCY

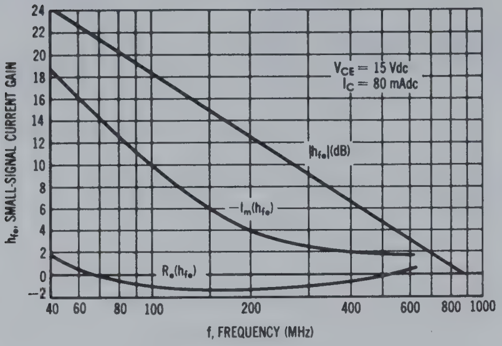


FIGURE 7 — OUTPUT CAPACITANCE versus COLLECTOR VOLTAGE

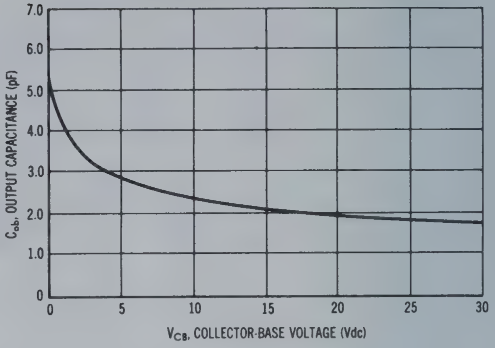


FIGURE 8 — f_T versus COLLECTOR CURRENT

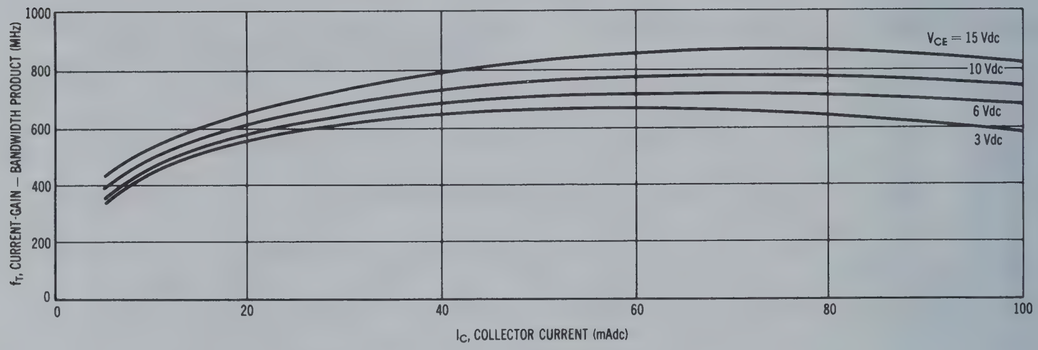


FIGURE 9 — $r_b'C_c$ versus COLLECTOR CURRENT

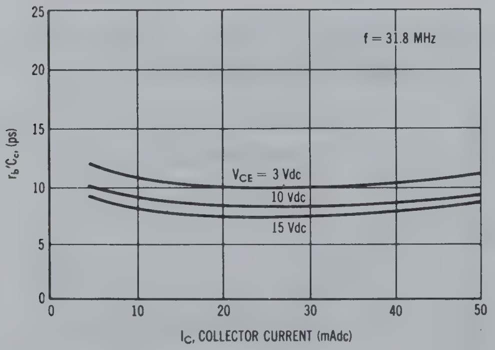
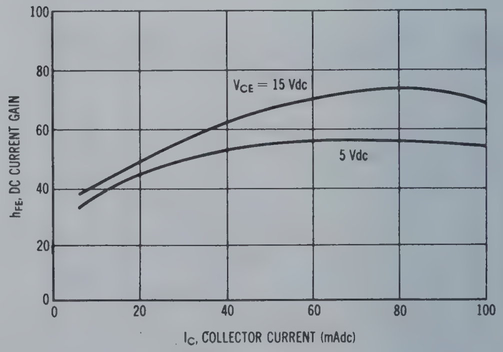


FIGURE 10 — DC CURRENT GAIN versus COLLECTOR CURRENT



y PARAMETER VARIATIONS

FIGURE 11 — SMALL-SIGNAL INPUT ADMITTANCE versus COLLECTOR CURRENT

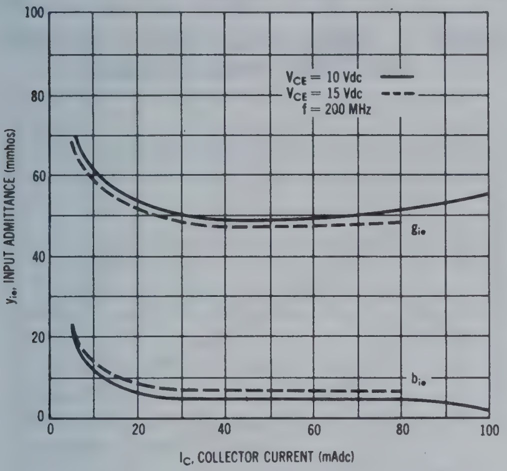


FIGURE 12 — SMALL-SIGNAL REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT

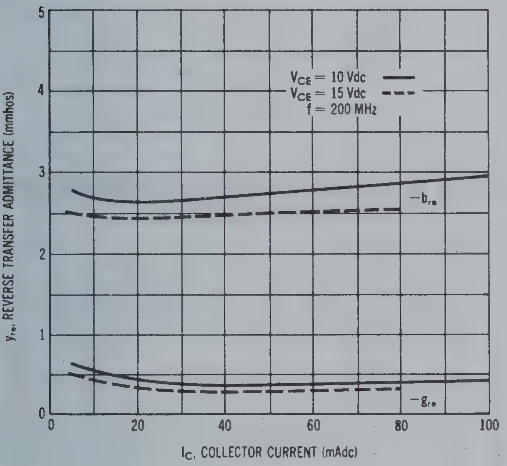


FIGURE 13 — SMALL-SIGNAL FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT

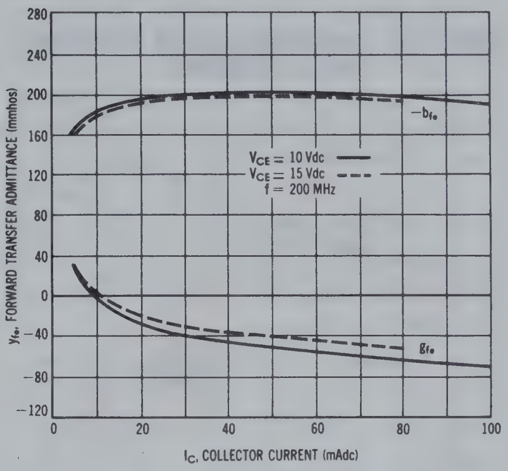
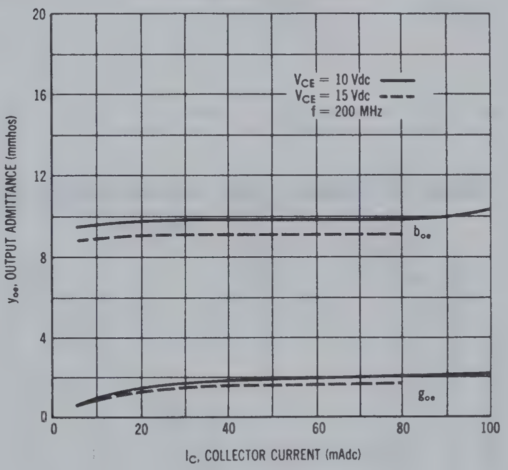


FIGURE 14 — SMALL-SIGNAL OUTPUT ADMITTANCE versus COLLECTOR CURRENT



DESIGN NOTE

Figures 11 through 18 show small-signal admittance-parameter data. This data can be used for Class A amplifier designs.

For Class C power-amplifier designs, the small-signal parameters are not applicable. Figures 4 and 5 give parallel output capacitance and the parallel input resistance and capacitance for Class C power-amplifier operation.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression

$$R_L' = \frac{V_{CC}^2}{2P}$$

where P = RF power output. The computed R_L' may then be combined with the data in Figures 2 and 3 to comprise complete device impedance data for Class C power amplifier design.

y PARAMETER VARIATIONS

($V_{CE} = 15$ Vdc, $I_C = 80$ mAdc, $T_A = 25°C$)

FIGURE 15 — SMALL-SIGNAL INPUT ADMITTANCE versus FREQUENCY

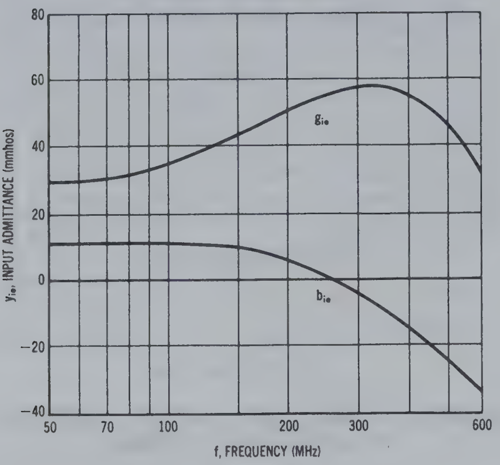


FIGURE 17 — SMALL-SIGNAL FORWARD TRANSFER ADMITTANCE versus FREQUENCY

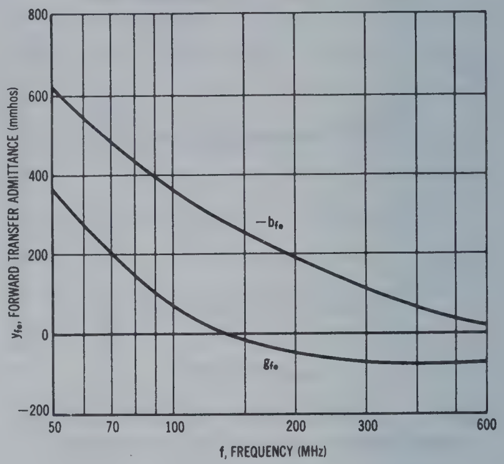


FIGURE 16 — SMALL-SIGNAL REVERSE TRANSFER ADMITTANCE versus FREQUENCY

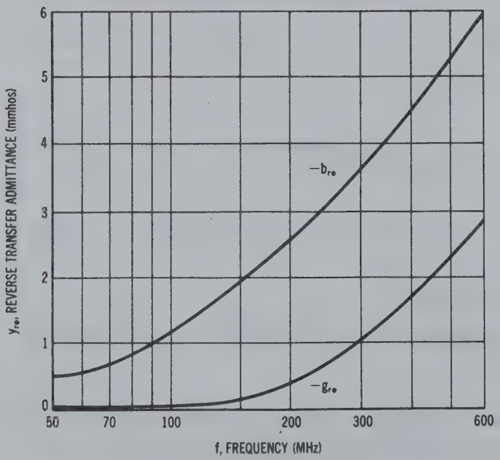
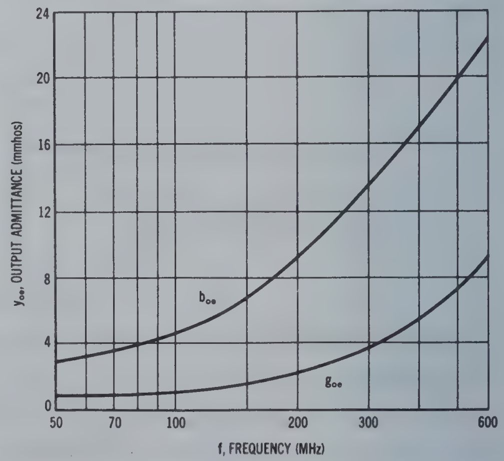


FIGURE 18 — SMALL-SIGNAL OUTPUT ADMITTANCE versus FREQUENCY



2N3870 thru 2N3873 (SILICON)
2N3896 thru 2N3899
2N6171 thru 2N6174

Advance Information

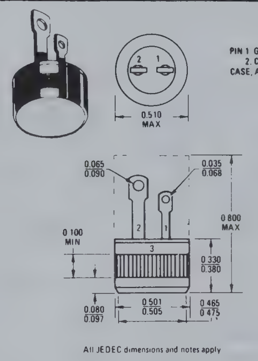
THYRISTORS
SILICON CONTROLLED RECTIFIERS

. . . designed for industrial and consumer applications such as power supplies, battery chargers, temperature, motor, light and welder controls.

- Economical for a Wide Range of Uses
- High Surge Current — I_{TSM} = 350 Amp
- Practical Level Triggering and Holding Characteristics — 10 mA (Typ) @ $T_C = 25^oC$
- Rugged Construction in Either Pressfit, Stud or Isolated Stud Package

THYRISTORS
PNPN

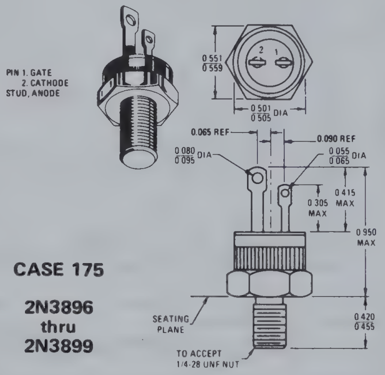
35 AMPERES RMS
100-600 VOLTS


PIN 1 GATE
2. CATHODE
CASE, ANODE
2
1
0.510
MAX
0.065
0.090
0.035
0.068
0 100
MIN
2
1
3
0 800
MAX
0 330
0.380
0.080
0.097
0.501
0.505
0 465
0 475

All JEDEC dimensions and notes apply

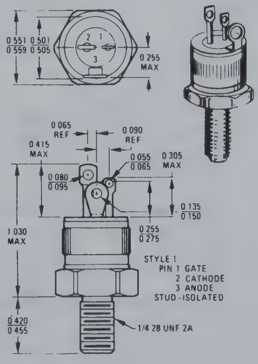
CASE 174
TO-203

2N3870
thru
2N3873


PIN 1. GATE
2. CATHODE
STUD, ANODE
2
1
0 551
0 559
0 501
0 505 DIA
0.065 REF
0.090 REF
0 080
0 095 DIA
0 055
0 065 DIA
0 415
0 305 MAX
MAX
0 950
MAX
SEATING
PLANE
0 420
0 455
TO ACCEPT
1/4-28 UNF NUT

CASE 175

2N3896
thru
2N3899


0 551 0.501
0 559 0 505
2 1
3
0 255
MAX
0 065
REF
0 090
REF
0 415
MAX
0 055
0 065
0 305
MAX
0 080
0 095
0 135
0 150
1 030
MAX
0 255
0 275
STYLE 1
PIN 1 GATE
2 CATHODE
3 ANODE
STUD-ISOLATED
0 420
0 455
1/4 28 UNF 2A

CASE 235

2N6171
thru
2N6174

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
*Repetitive Peak Reverse Blocking Voltage (1) (T_J = -40 to +100°C) 1/2 Sine Wave, 50 to 400 Hz, Gate Open 2N3870, 2N3896, 2N6171 2N3871, 2N3897, 2N6172 2N3872, 2N3898, 2N6173 2N3873, 2N3899, 2N6174	V_{DRM}	 100 200 400 600	Volts
*Non-Repetitive Peak Reverse Blocking Voltage (t ≤ 5.0 ms) 2N3870, 2N3896, 2N6171 2N3871, 2N3897, 2N6172 2N3872, 2N3898, 2N6173 2N3873, 2N3899, 2N6174	V_{RSM}	 150 330 660 700	Volts
*Forward Current AVG (T_C = -40 to +65°C) (+85°C)	$I_{T(AV)}$	 22 11	Amp
*Peak Surge Current (One cycle, 60 Hz) (T_C = +65°C)	I_{TSM}	350	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C) (t = 1.0 to 8.3 ms)	I^2t	435	A^2s
*Peak Gate Power	P_{GM}	20	Watts
*Average Gate Power	$P_{G(AVG)}$	0.5	Watt
*Peak Forward Gate Current	I_{GFM}	2.0	Amp
Peak Gate Voltage	V_{GM}	10	Volts
*Operating Junction Temperature Range	T_J	-40 to +100	°C
*Storage Temperature Range	T_{stg}	-40 to +150	°C
Stud Torque 2N3896 thru 2N3899 2N6171 thru 2N6174	—	30	in. lb.

***THERMAL CHARACTERISTICS**

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case 2N3870 thru 2N3873, 2N3896 thru 2N3899 2N6171 thru 2N6174	θ_{JC}	 0.9 1.0	°C/W

*Indicates JEDEC Registered Data.

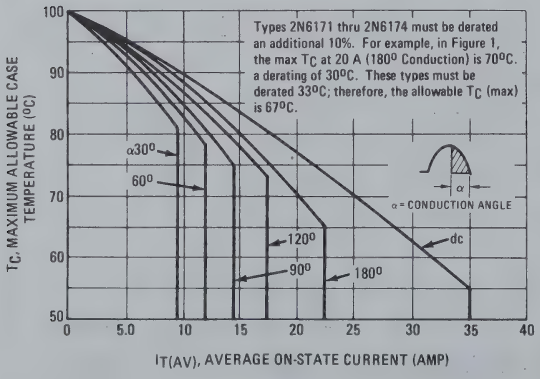
(1) Ratings apply for zero or negative gate voltage. Devices shall not have a positive bias applied to the gate concurrently with a negative potential on the anode. Devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
* Peak Forward Blocking Voltage (T_J = 100°C)	V_{DRM}				Volts
2N3870, 2N3896, 2N6171		100	–	–	
2N3871, 2N3897, 2N6172		200	–	–	
2N3872, 2N3898, 2N6173		400	–	–	
2N3873, 2N3899, 2N6174		600	–	–	
* Peak Forward Blocking Current (Rated V_{DRM}, with gate open, T_J = 100°C)	I_{DRM}				mA
2N3870, 2N3896, 2N6171		–	1.0	2.0	
2N3871, 2N3897, 2N6172		–	1.0	2.5	
2N3872, 2N3898, 2N6173		–	1.0	3.0	
2N3873, 2N3899, 2N6174		–	1.0	4.0	
* Peak Reverse Blocking Current (Rated V_{RRM}, with gate open, T_J = 100°C)	I_{RRM}				mA
2N3870, 2N3896, 2N6171		–	1.0	2.0	
2N3871, 2N3897, 2N6172		–	1.0	2.5	
2N3872, 2N3898, 2N6173		–	1.0	3.0	
2N3873, 2N3899, 2N6174		–	1.0	4.0	
* Forward "On" Voltage (I_{TM} = 69 A Peak)	V_{TM}	–	1.5	1.85	Volts
Gate Trigger Current, Continuous dc *T_C = −40°C	I_{GT}	–	–	80	mA
(Anode Voltage = 12 V, R_L = 24 Ω) T_C = 25°C		–	10	40	
Gate Trigger Voltage, Continuous dc	V_{GT}				Volts
(Anode Voltage = 12 V, R_L = 24 Ω) *T_C = −40°C		–	0.8	3.0	
(Anode Voltage = Rated V_{DM}, R_L = 100 Ω, T_J = 100°C) T_C = 25°C		–	–	1.6	
Holding Current *T_C = −40°C	I_H	–	–	90	mA
(Anode Voltage = 12 V, Gate Open) T_C = 25°C R_S = 50 Ohms) Peak Initiating On-State Current = 200 mA		–	10	50	
*Turn-On Time (t_d + t_r) (I_{TM} = 41 Adc, I_{GT} =200mAdc V = rated V_{DRM}, R_S = 250 Ohms, Rise Time = 0.05 μs, Pulse Width = 10 μs)	t_{on}	–	–	1.5	mA
Turn-Off Time	t_{off}				μs
(I_{TM} = 10 A, I_R = 10 A)		–	15	–	
(I_{TM} = 10 A, I_R = 10 A, T_J = 100°C)		–	25	–	
Forward Voltage Application Rate (T_J = 100°C)	dv/dt	–	50	–	V/μs

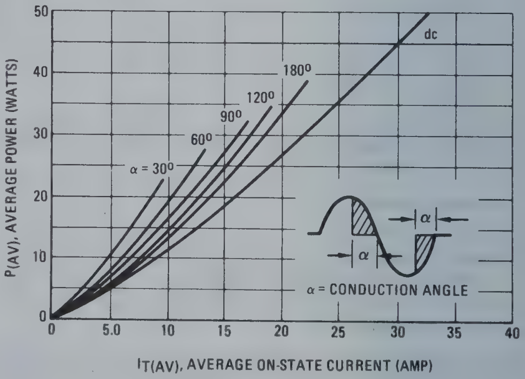
*Indicates JEDEC Registered Data.

FIGURE 1 – CURRENT DERATING



Types 2N6171 thru 2N6174 must be derated an additional 10%. For example, in Figure 1, the max T_C at 20 A (180° Conduction) is 70°C. a derating of 30°C. These types must be derated 33°C; therefore, the allowable T_C (max) is 67°C.

FIGURE 2 – POWER DISSIPATION



2N3883 (GERMANIUM)

CASE 31
(TO-5)

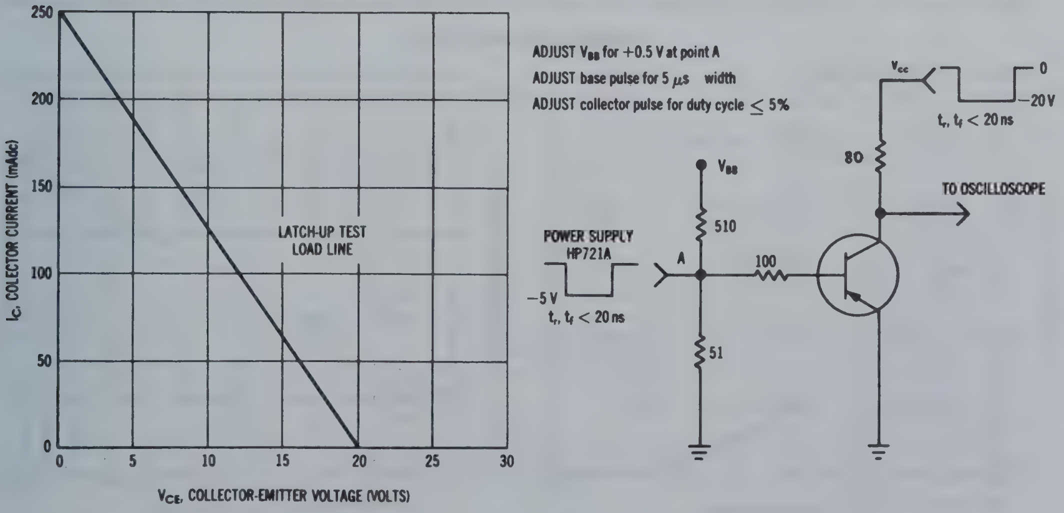
Collector connected to case

Medium-current, germanium PNP high-speed switching transistor.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Units
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current (Continuous)	I_C	300	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Device Dissipation @ 25°C Case Temperature (Derate 10 mW/°C above 25°C)	P_D	750	mW
Device Dissipation @ 25°C Ambient (Derate 4 mW/°C)	P_D	300	mW

COLLECTOR LATCH-UP VOLTAGE AND TEST CIRCUIT



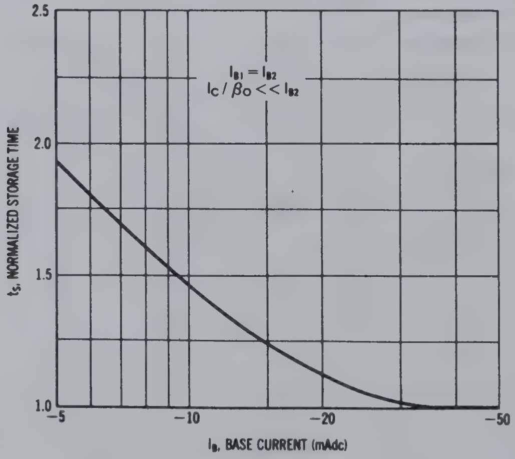
ADJUST V_{BB} for +0.5 V at point A
ADJUST base pulse for 5 μs width
ADJUST collector pulse for duty cycle ≤ 5%

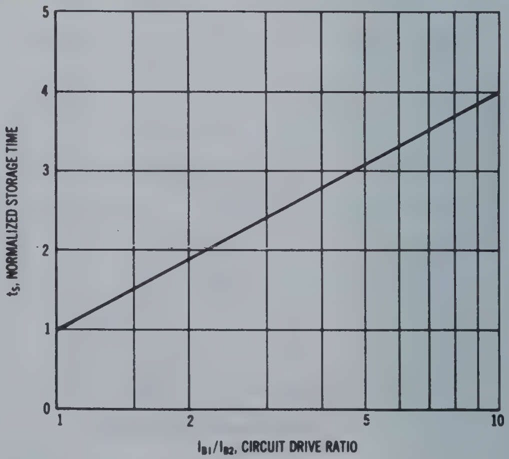
2N3883 (continued)

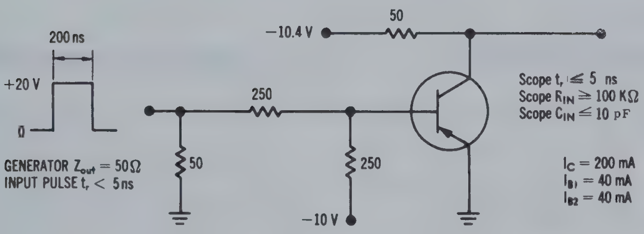
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100μAdc, I_E = 0)	BV_{CBO}	25	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10mAdc, I_B = 0)	BV_{CEO}	15	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100μAdc, I_C = 0)	BV_{EBO}	3.0	—	—	Vdc
Latch-Up Voltage	LV_{CEX}	20	—	—	Vdc
Collector-Emitter Leakage Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_{CES}	—	—	100	μAdc
Base Cutoff Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_B	—	—	100	μAdc
DC Current Gain (I_C = 200 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	—	—	—
Collector-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 40 mAdc	$V_{CE(sat)}$	—	0.35	0.5	Vdc
Base-Emitter Voltage (I_C = 200 mAdc, I_B = 40 mAdc)	V_{BE}	0.4	0.65	0.9	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	4.5	8.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	10	25	pF
Current-Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 40 mAdc, f = 100 MHz)	f_T	100	300	—	MHz
Delay Time	t_d	—	8.0	15	ns
Rise Time	t_r	—	28	40	ns
Storage Time	t_s	—	40	70	ns
Fall Time	t_f	—	28	40	ns

STORAGE TIME VARIATIONS

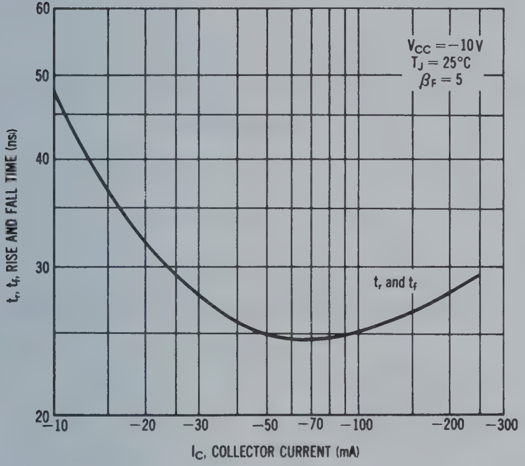




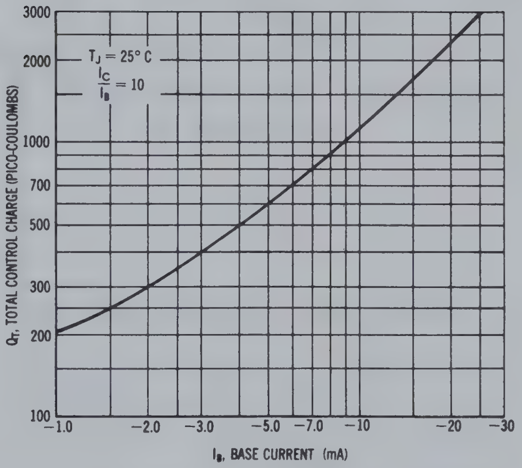


SWITCHING TIME TEST CIRCUIT

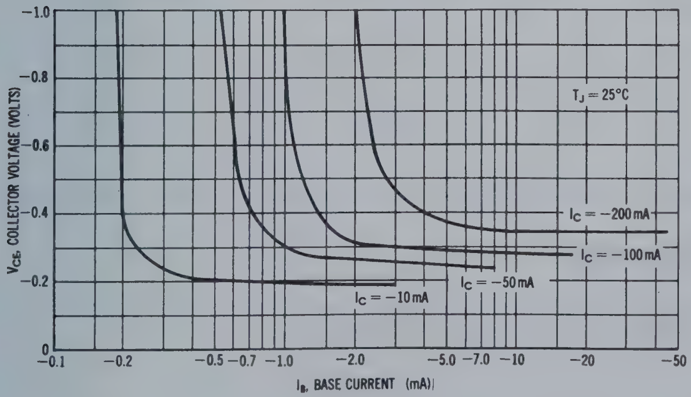
200 ns
+20 V
0
GENERATOR $Z_{out} = 50\Omega$
INPUT PULSE $t_r < 5$ ns
50
250
250
−10 V
50
−10.4 V
Scope $t_r \leq 5$ ns
Scope $R_{IN} \geq 100$ KΩ
Scope $C_{IN} \leq 10$ pF
$I_C = 200$ mA
$I_{B1} = 40$ mA
$I_{B2} = 40$ mA



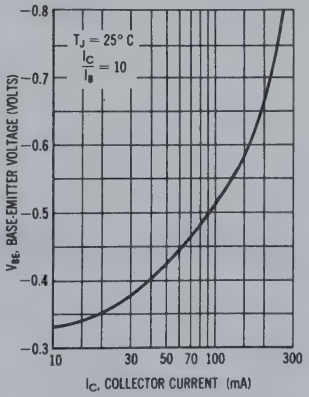
TYPICAL RISE AND FALL TIME BEHAVIOR



TOTAL CONTROL CHARGE

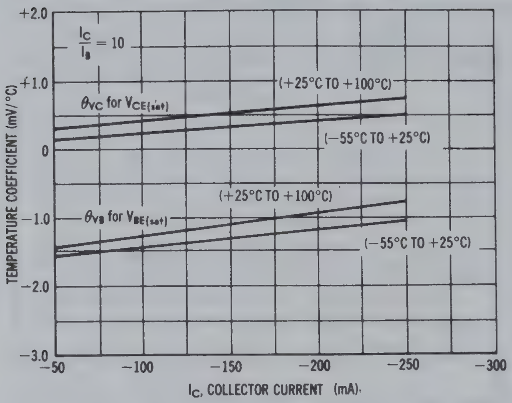


COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

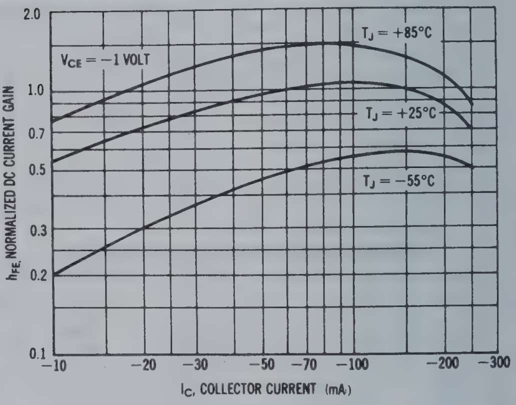


BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

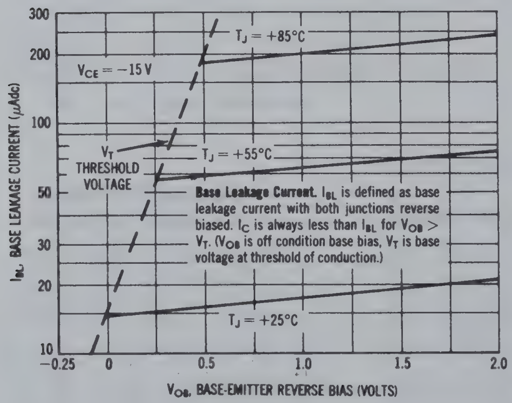
TEMPERATURE COEFFICIENTS



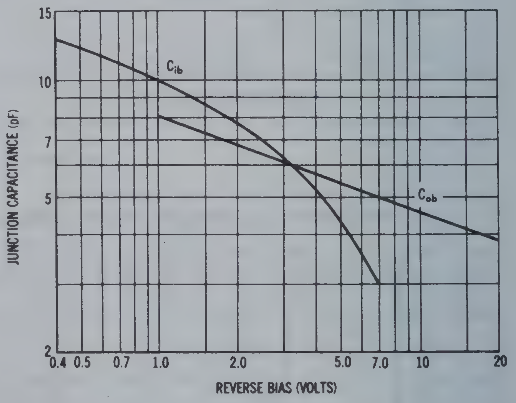
NORMALIZED CURRENT GAIN CHARACTERISTICS



LEAKAGE CHARACTERISTICS COMMON EMITTER



JUNCTION CAPACITANCE versus REVERSE VOLTAGE



2N3896 thru 2N3899 (SILICON)

For Specifications, See 2N3870 Data

2N3902 NPN (SILICON)
2N5157

HIGH VOLTAGE NPN SILICON TRANSISTORS

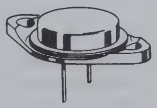
. . . designed for use in high-voltage inverters, converters, switching regulators and line operated amplifiers.

- High Collector-Emitter Voltage — V_{CEX} = 700 Vdc
- Excellent DC Current Gain —
  h_{FE} = 10 (Min) @ I_C = 2.5 Adc
- Low Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.8 Vdc (Max) @ I_C = 1.0 Adc

3.5 AMPERE

POWER TRANSISTORS
NPN SILICON

400 and 500 VOLTS
100 WATTS



*MAXIMUM RATINGS

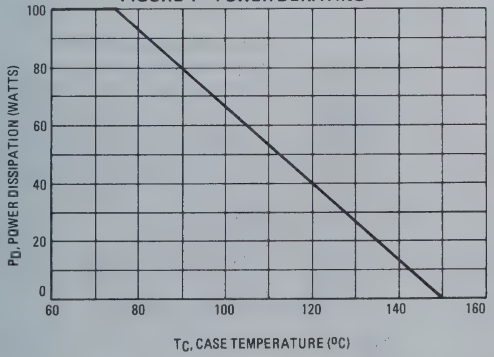
Rating	Symbol	2N3902	2N5157	Unit
Collector-Emitter Voltage	V_{CEO}	400	500	Vdc
Collector-Emitter Voltage	V_{CEX}	700		Vdc
Emitter-Base Voltage	V_{EB}	5.0	6.0	Vdc
Collector Current — Continuous	I_C	3.5		Adc
Base Current	I_B	2.0		Adc
Total Device Dissipation @ T_C = 75°C Derate above 75°C	P_D	100 1.33		Watts W/°C
Operating Junction Temperature Range	T_J	-65 to +150		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

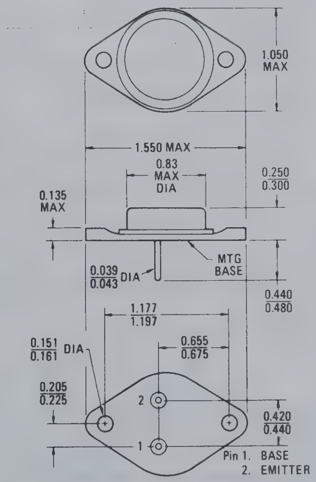
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.75	°C/W

*Indicates JEDEC Registered Data

FIGURE 1 — POWER DERATING




1.050 MAX
1.550 MAX
0.83 MAX DIA
0.250 0.300
0.135 MAX
MTG BASE
0.039 0.043 DIA
0.440 0.480
1.177 1.197
0.151 0.161 DIA
0.655 0.675
0.205 0.225
2
1
0.420 0.440
Pin 1. BASE
2. EMITTER

To convert inches to millimeters multiply by 25.4
All JEDEC dimensions and notes apply
Collector connected to case

CASE 11
TO-3

***ELECTRICAL CHARACTERISTICS** ($T_C = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 100 mAdc, I_B = 0) (See Figure 12)	2N3902 2N5157	$V_{CEO(sus)}$	325 400	– –	Vdc
Collector-Emitter Breakdown Voltage (I_C = 3.5 Adc, R_{BE} = 10 Ohms) (See Figure 12)	2N5157	BV_{CER}	500	–	Vdc
Collector Cutoff Current (V_{CE} = 400 Vdc, I_B = 0) (V_{CE} = 500 Vdc, I_B = 0)	2N3902 2N5157	I_{CEO}	0.25 0.25	– –	mAdc
Collector Cutoff Current (V_{CE} = 700 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 400 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 125^{o}C)	2N3902 2N5157 Both Types	I_{CEX}	– – –	2.5 0.5 0.5	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0) (V_{BE} = 6.0 Vdc, I_C = 0).	2N3902 2N5157	I_{EBO}	– –	5.0 5.0	mAdc
ON CHARACTERISTICS(1)					
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc) (I_C = 2.5 Adc, V_{CE} = 5.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc, T_C = –55^{o}C)	2N3902,2N5157 2N3902,2N5157 2N5157	h_{FE}	30 10 10	90 – –	–
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc) (I_C = 2.5 Adc, I_B = 0.5 Adc) (I_C = 3.5 Adc, I_B = 0.7 Adc)	2N3902,2N5157 2N3902 2N5157	$V_{CE(sat)}$	– – –	0.8 2.5 2.5	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc) (I_C = 2.5 Adc, I_B = 0.5 Adc) (I_C = 3.5 Adc, I_B = 0.7 Adc)	2N3902,2N5157 2N3902 2N5157	$V_{BE(sat)}$	– – –	1.5 2.0 2.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 0.2 Adc, V_{CE} = 10 Vdc) (I_C = 0.2 Adc, V_{CE} = 12 Vdc)	2N3902 2N5157	f_T	2.8 2.8	– –	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 1.0 MHz)	2N5157	C_{ob}	–	150	pF
SWITCHING CHARACTERISTICS					
Turn-On Time (V_{CC} = 125 Vdc, I_C = 1.0 Adc, I_{B1} = 0.1 Adc)	2N5157	t_{on}	–	0.8	μs
Turn-Off Time (V_{CC} = 125 Vdc, I_C = 1.0 Adc, I_{B1} = 0.1 Adc, I_{B2} = 0.5 Adc)	2N5157	t_{off}	–	1.7	μs

*Indicates JEDEC Registered Data

(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 2 — SWITCHING TIMES TEST CIRCUIT

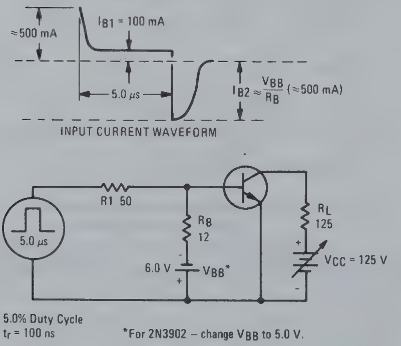


FIGURE 3 — TURN-ON TIME

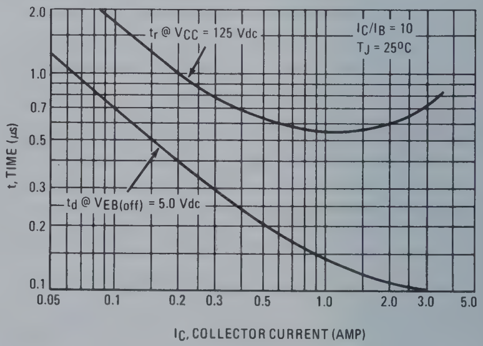


FIGURE 4 — THERMAL RESPONSE

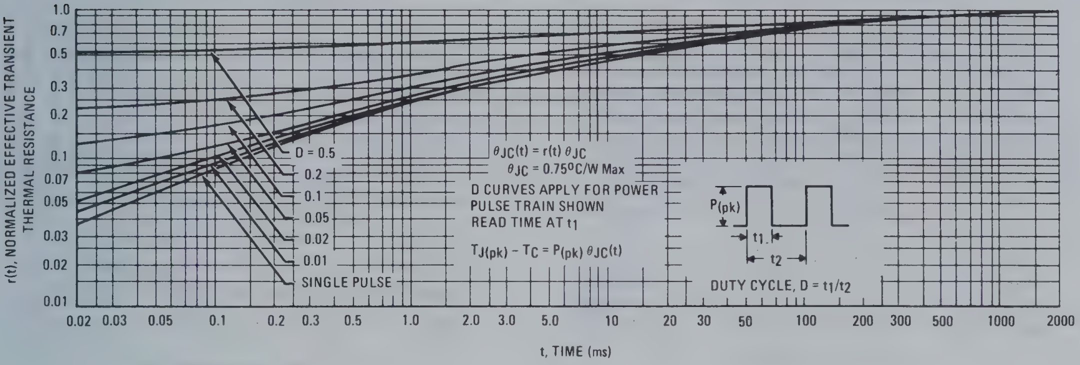
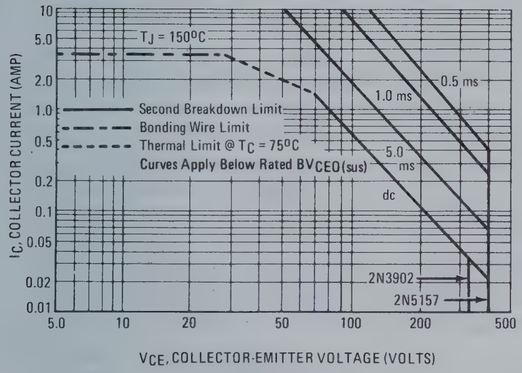


FIGURE 5 — ACTIVE-REGION SAFE-OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 150^{\circ}C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 150^{\circ}C$. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown. (See AN-415)

FIGURE 6 — TURN-OFF TIME

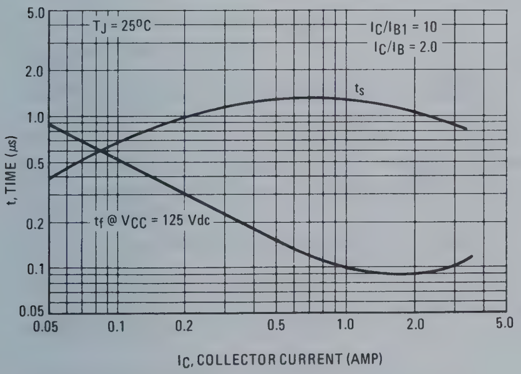


FIGURE 7 — CAPACITANCE

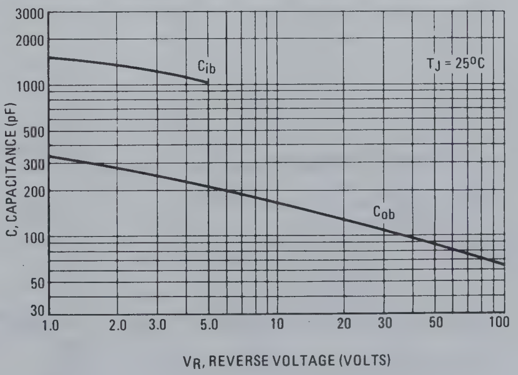


FIGURE 8 – DC CURRENT GAIN

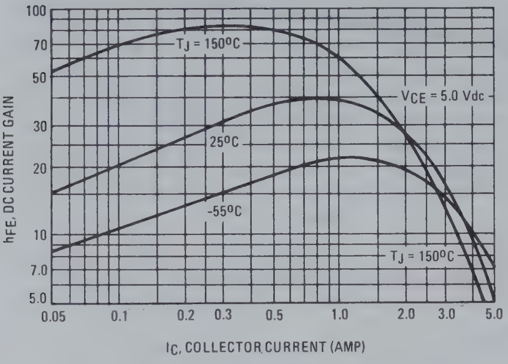


FIGURE 9 – "ON" VOLTAGES

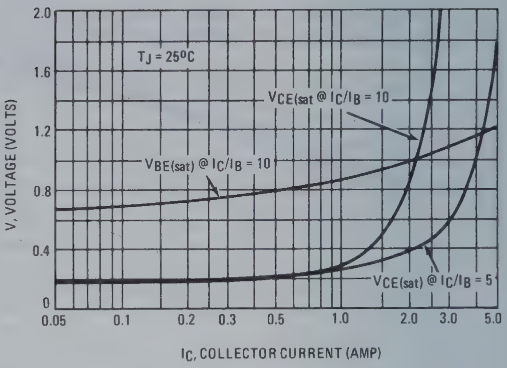


FIGURE 10 – COLLECTOR CUT-OFF REGION

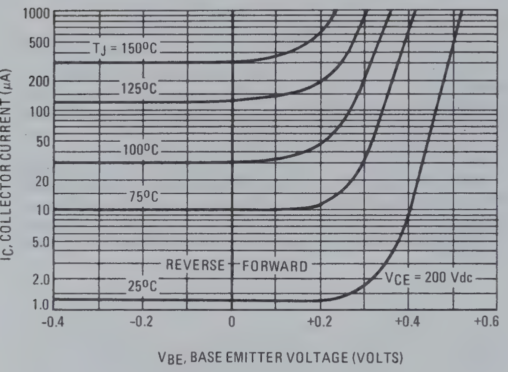


FIGURE 11 – TEMPERATURE COEFFICIENTS

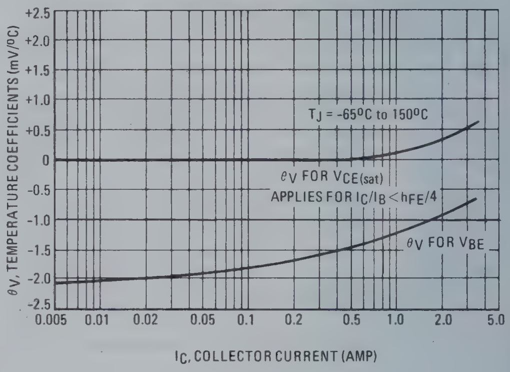
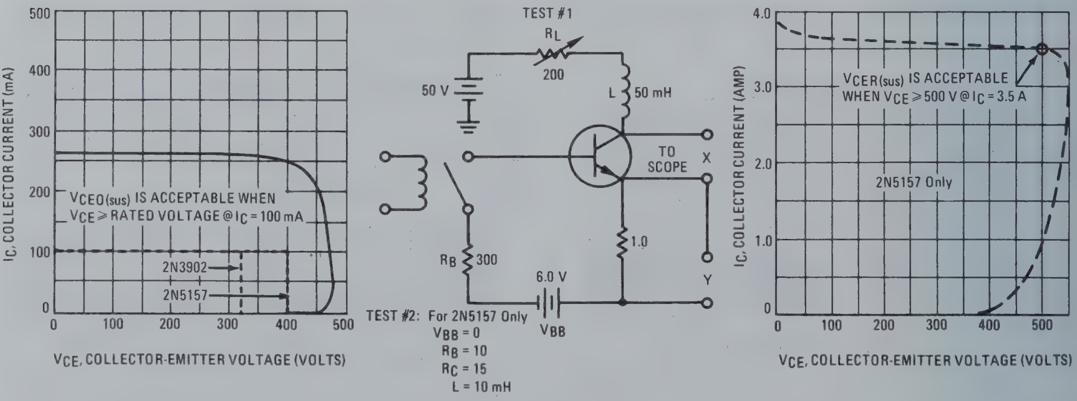
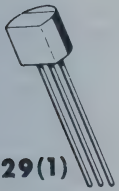


FIGURE 12 – COLLECTOR-EMITTER SUSTAINING VOLTAGE TEST CIRCUITS AND LOAD LINES


IC, COLLECTOR CURRENT (mA)
500
400
300
200
100
0
VCEO(sus) IS ACCEPTABLE WHEN
VCE ≥ RATED VOLTAGE @ IC = 100 mA
2N3902
2N5157
0
100
200
300
400
500
VCE, COLLECTOR-EMITTER VOLTAGE (VOLTS)
TEST #1
RL
200
50 V
L
50 mH
TO
SCOPE
X
Y
RB
300
1.0
6.0 V
VBB
TEST #2: For 2N5157 Only
VBB = 0
RB = 10
RC = 15
L = 10 mH
IC, COLLECTOR CURRENT (AMP)
4.0
3.0
2.0
1.0
0
VCER(sus) IS ACCEPTABLE
WHEN VCE ≥ 500 V @ IC = 3.5 A
2N5157 Only
0
100
200
300
400
500
VCE, COLLECTOR-EMITTER VOLTAGE (VOLTS)

2N3903 (SILICON)
2N3904



CASE 29(1)
(TO-92)

NPN silicon annular transistors, designed for general-purpose switching and amplifier applications, features one-piece, injection-molded plastic package for high reliability. The 2N3903 and 2N3904 are complementary with PNP types 2N3905 and 2N3906, respectively.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	350 2.73	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)			BV_{CBO}	60	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 1.0 mAdc, I_B = 0)			BV_{CEO}*	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)			BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 3.0 Vdc)			I_{CEX}	-	50	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 3.0 Vdc)			I_{BL}	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904	15	h_{FE}*	20 40	- -	-
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			35 70	- -	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			50 100	150 300	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			30 60	- -	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			15 30	- -	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		16, 17	$V_{CE(sat)}$*	- -	0.2 0.3	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		17	$V_{BE(sat)}$*	0.65 -	0.85 0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3903 2N3904		f_T	250 300	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		3	C_{ob}	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		3	C_{ib}	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	13	h_{ie}	0.5 1.0	8.0 10	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	14	h_{re}	0.1 0.5	5.0 8.0	X 10-4
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	11	h_{fe}	50 100	200 400	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		12	h_{oe}	1.0	40	µmhos
Noise Figure (I_C = 100 µAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k ohms, f = 10 Hz to 15.7 kHz)	2N3903 2N3904	9, 10	NF	- -	6.0 5.0	dB
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	1, 5	t_d	-	35	ns
Rise Time		1, 5, 6	t_r	-	35	ns
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc) 2N3903 2N3904	2, 7	t_s	- -	175 200	ns
Fall Time		2, 8	t_f	-	50	ns

* Pulse Test: Pulse Width = 300 µs, Duty Cycle = 2.0%.

FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

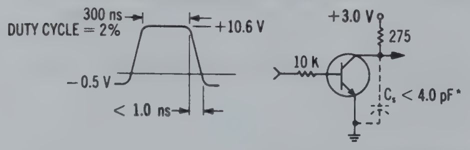
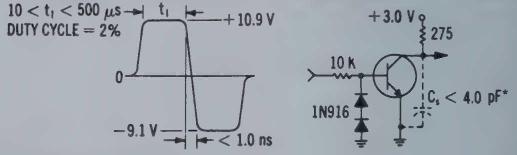


FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT



*Total shunt capacitance of test jig and connectors

TRANSIENT CHARACTERISTICS

— $T_J = 25°C$ --- $T_J = 125°C$

FIGURE 3 — CAPACITANCE

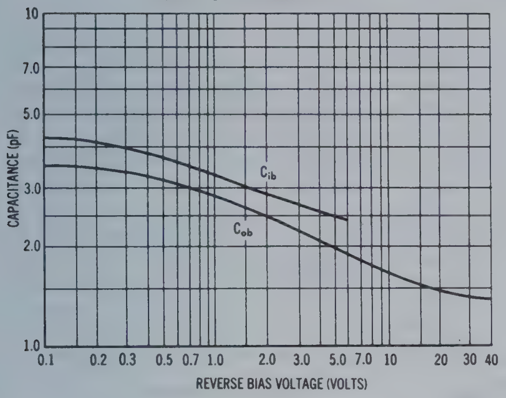


FIGURE 4 — CHARGE DATA

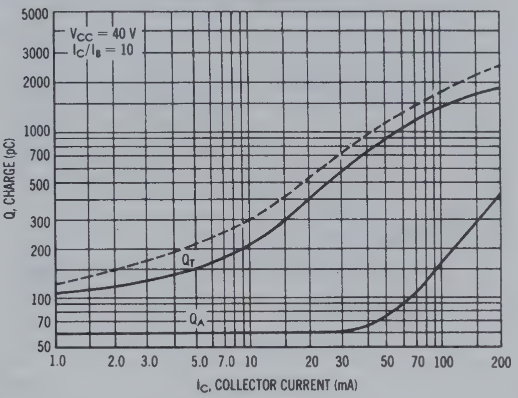


FIGURE 5 — TURN-ON TIME

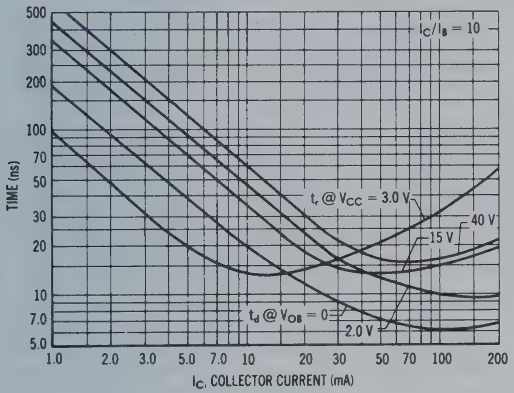


FIGURE 6 — RISE TIME

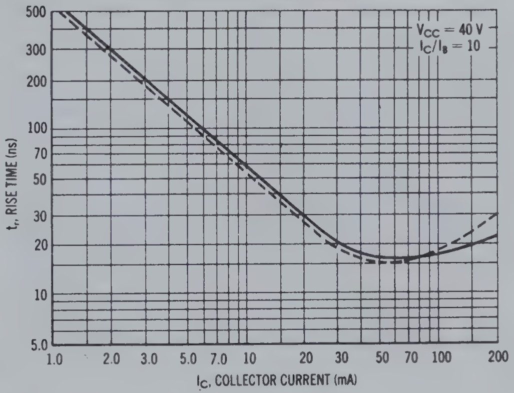


FIGURE 7 — STORAGE TIME

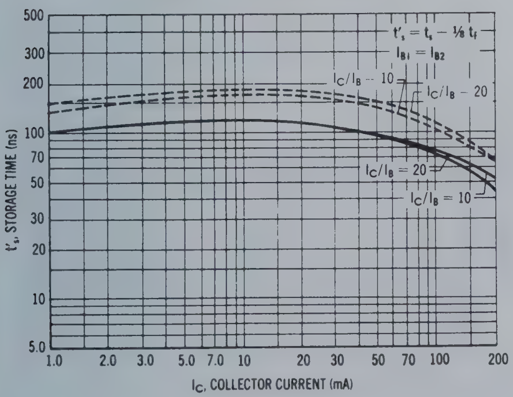
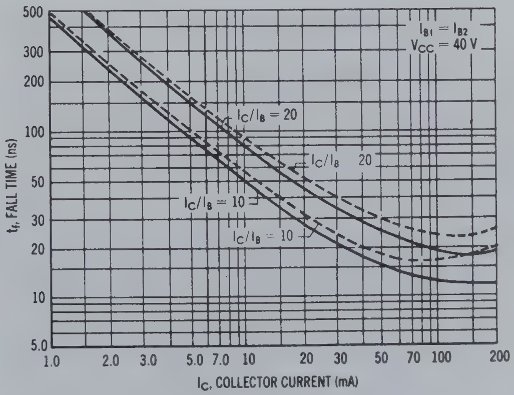


FIGURE 8 — FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

$V_{CE} = 5.0$ Vdc, $T_A = 25°C$

FIGURE 9

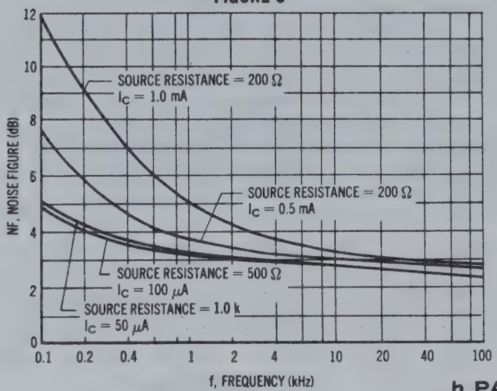
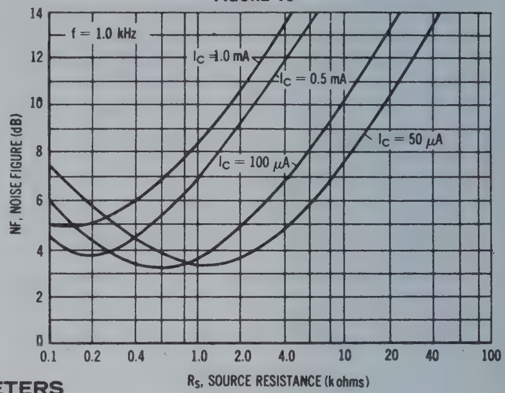


FIGURE 10



h PARAMETERS

($V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$)

FIGURE 11 — CURRENT GAIN

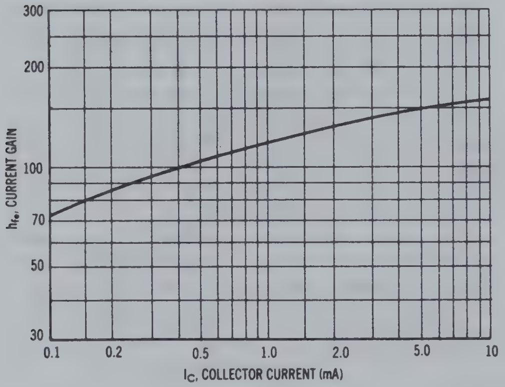


FIGURE 12 — OUTPUT ADMITTANCE

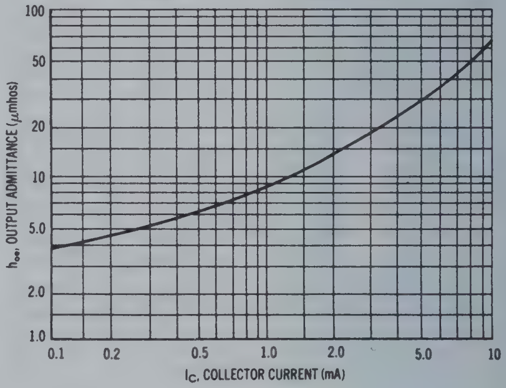


FIGURE 13 — INPUT IMPEDANCE

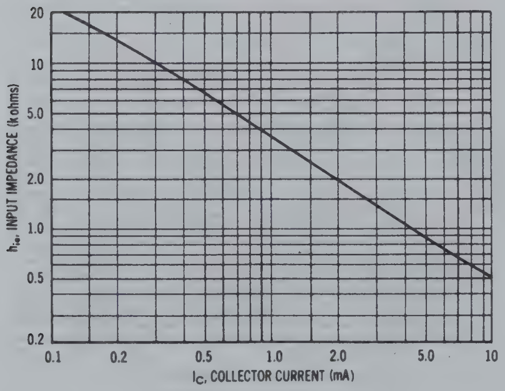
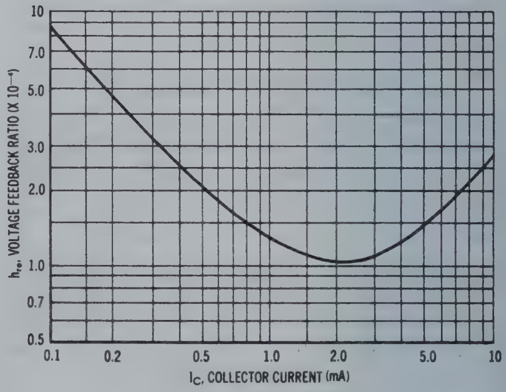


FIGURE 14 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 15 — NORMALIZED CURRENT GAIN

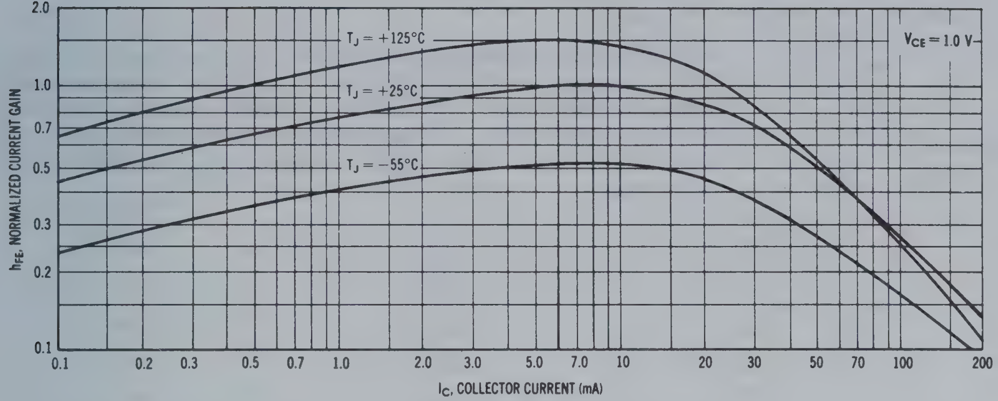


FIGURE 16 — COLLECTOR SATURATION REGION

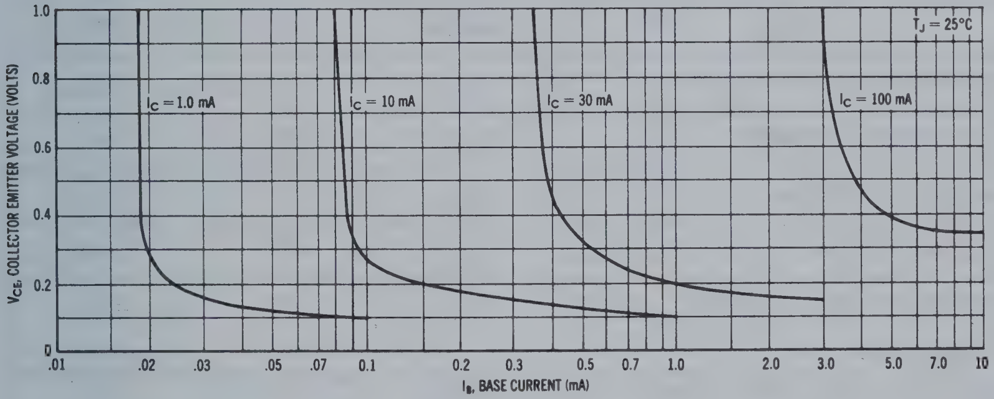


FIGURE 17 — "ON" VOLTAGES

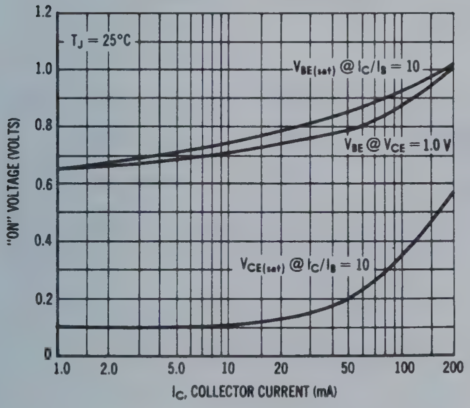
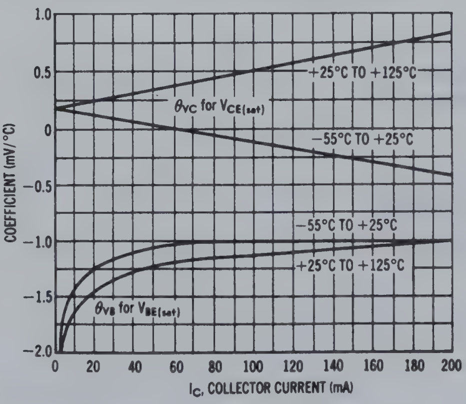
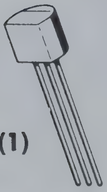


FIGURE 18 — TEMPERATURE COEFFICIENTS



2N3905 (SILICON)
2N3906



CASE 29(1)
(TO-92)

PNP silicon annular **transistors**, designed for general purpose switching and amplifier applications, features one-piece, injection-molded plastic package for high reliability. The 2N3905 and 2N3906 are complementary with NPN types 2N3903 and 2N3904, respectively.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C	P_D	350	mW
Derate above 25°C		2.73	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)			BV_{CBO}	40	-	Vdc
Collector-Emitter Breakdown Voltage (1) (I_C = 1.0 mAdc, I_B = 0)			BV_{CEO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3.0 Vdc)			I_{CEX}	-	50	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3.0 Vdc)			I_{BL}	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain (1) (I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N3905 2N3906	15	h_{FE}	30 60	- -	-
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)	2N3905 2N3906			40 80	- -	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3905 2N3906			50 100	150 300	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	2N3905 2N3906			30 60	- -	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3905 2N3906			15 30	- -	
Collector-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		16, 17	$V_{CE(sat)}$	- -	0.25 0.4	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		17	$V_{BE(sat)}$	0.65 -	0.85 0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3905 2N3906		f_T	200 250	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		3	C_{ob}	-	4.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		3	C_{ib}	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3905 2N3906	13	h_{ie}	0.5 2.0	8.0 12	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3905 2N3906	14	h_{re}	0.1 1.0	5.0 10	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3905 2N3906	11	h_{fe}	50 100	200 400	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3905 2N3906	12	h_{oe}	1.0 3.0	40 60	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k ohm, f = 10 Hz to 15.7 kHz)	2N3905 2N3906	9, 10	NF	- -	5.0 4.0	dB
SWITCHING CHARACTERISTICS						
Delay Time — (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1.0 mAdc)		1, 5	t_d	-	35	ns
Rise Time		1, 5, 6	t_r	-	35	ns
Storage Time — (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc)	2N3905 2N3906	2, 7	t_s	- -	200 225	ns
Fall Time	2N3905 2N3906	2, 8	t_f	- -	60 75	ns

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

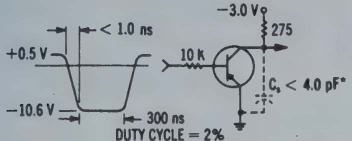
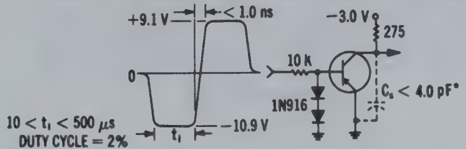


FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT



*Total shunt capacitance of test jig and connectors

TRANSIENT CHARACTERISTICS

—— $T_J = 25°C$ - - - $T_J = 125°C$

FIGURE 3 — CAPACITANCE

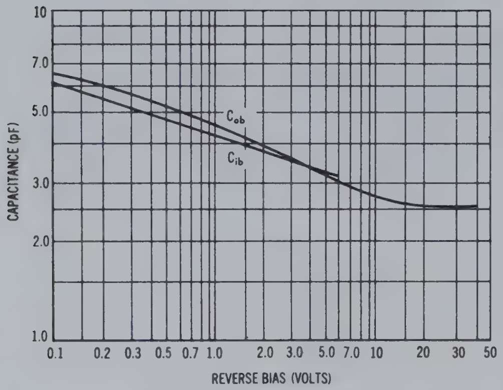


FIGURE 4 — CHARGE DATA

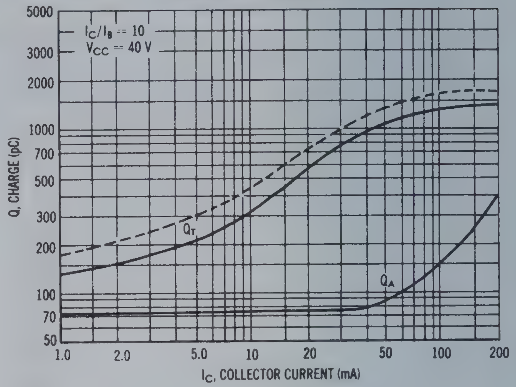


FIGURE 5 — TURN-ON TIME

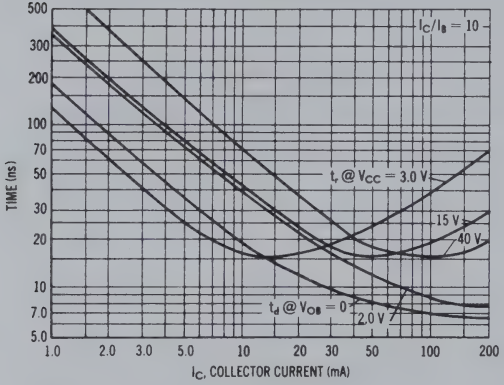


FIGURE 6 — RISE TIME

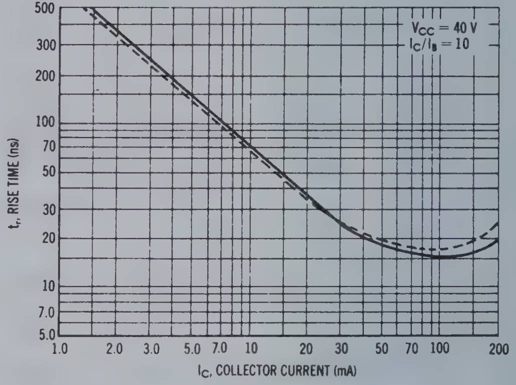


FIGURE 7 — STORAGE TIME

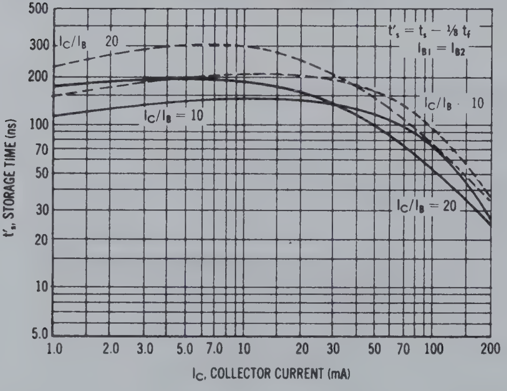
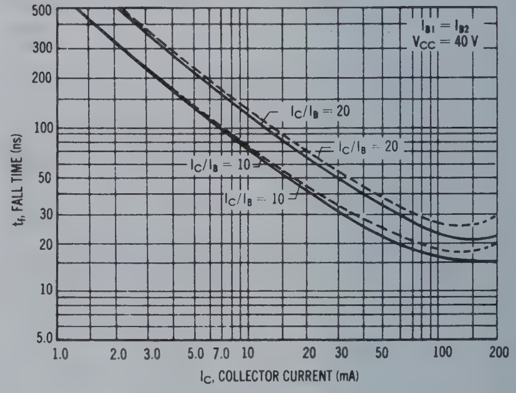


FIGURE 8 — FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

$V_{CE} = 5.0$ Vdc, $T_A = 25°C$

FIGURE 9

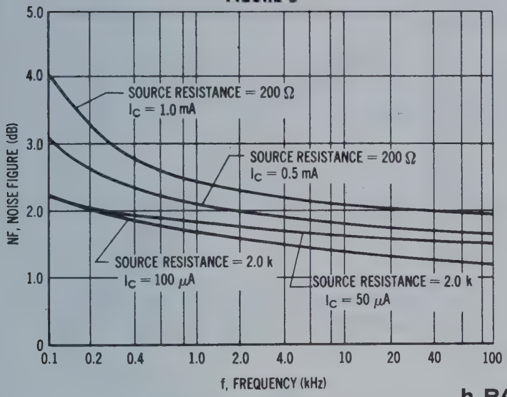
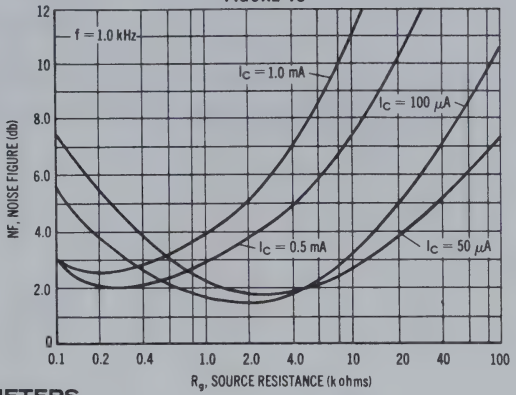


FIGURE 10



h PARAMETERS

($V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$)

FIGURE 11 — CURRENT GAIN

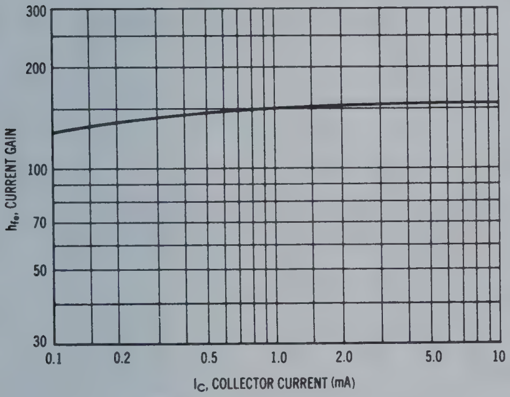


FIGURE 12 — OUTPUT ADMITTANCE

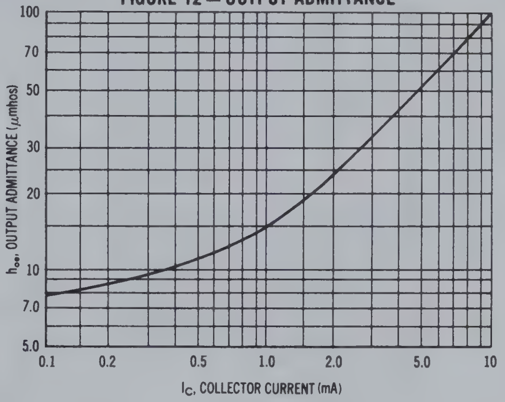


FIGURE 13 — INPUT IMPEDANCE

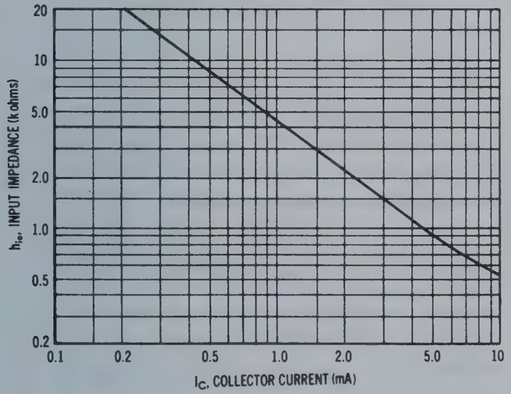
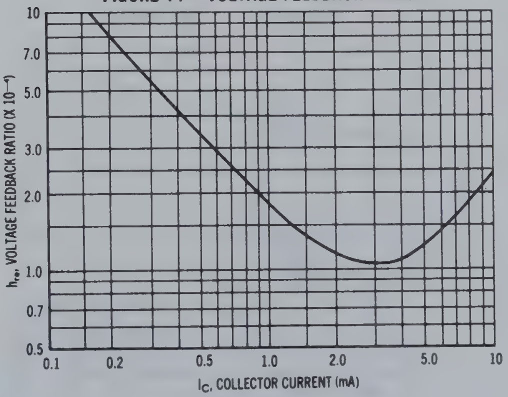


FIGURE 14 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 15 — NORMALIZED CURRENT GAIN

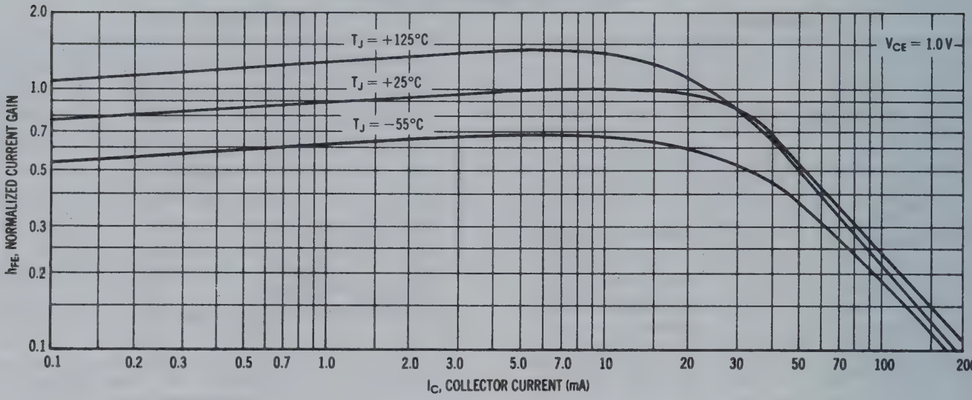


FIGURE 16 — COLLECTOR SATURATION REGION

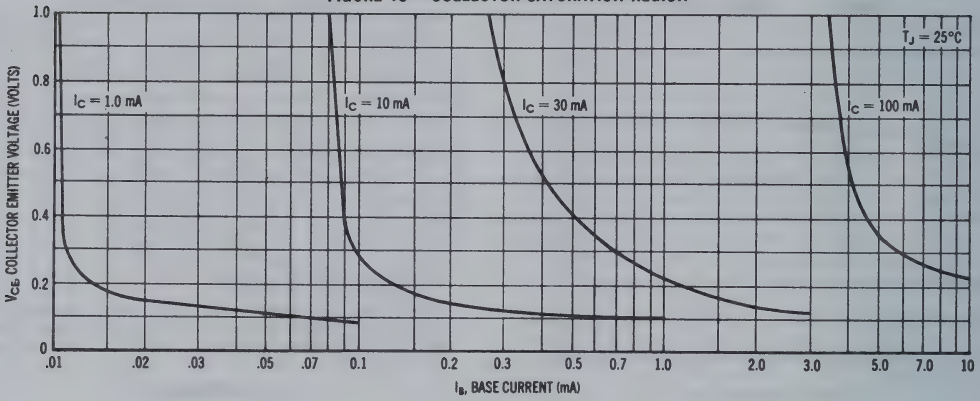


FIGURE 17 — "ON" VOLTAGES

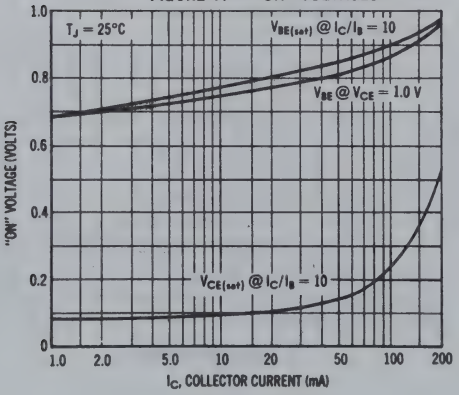
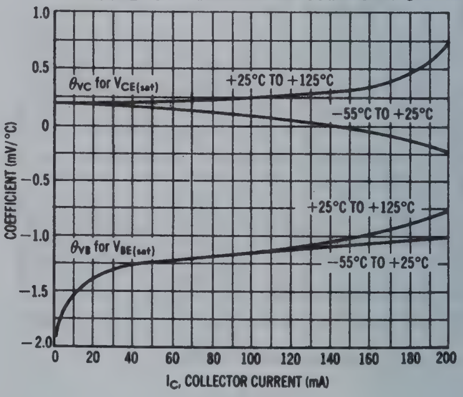


FIGURE 18 — TEMPERATURE COEFFICIENTS



2N3909 (SILICON)
2N3909A

P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)

SILICON P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

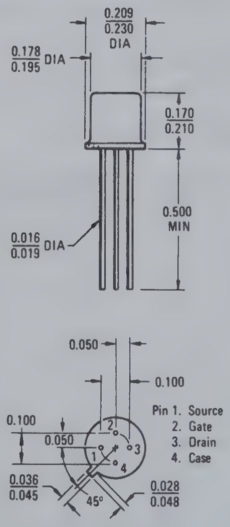
Depletion Mode (Type A) Junction Field-Effect Transistors designed primarily for low-power audio amplifier applications.

- High AC Input Resistance – Typically > 30 Megohms @ f = 1.0 kHz
- Drain and Source Interchangeable
- Active Elements Isolated from Case

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-20	Vdc
Drain-Gate Voltage	V_{DG}	-20	Vdc
Reverse Gate-Source Voltage	V_{GSR}	20	Vdc
Forward Gate-Source Voltage	V_{GSF}	20	Vdc
Forward Gate Current	I_{GF}	10	mAdc
Total Device Dissipation @ $T_A = 25^\circ C$ Derate above $25^\circ C$	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
0.100
0.100
0.050
1
2
3
4
Pin 1. Source
2. Gate
3. Drain
4. Case
0.036
0.045
45°
0.028
0.048

TO-72
CASE 20 (5)

Case Connected
to Source

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) (Note 1)

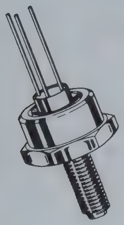
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	20	–	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 10 Vdc, I_D = 10 μAdc)	2N3909 2N3909A	$V_{GS(off)}$	– –	8.0 8.0	Vdc
Gate Reverse Current (V_{GS} = 10 Vdc, V_{DS} = 0) (V_{GS} = 10 Vdc, V_{DS} = 0, T_A = 100°C)		I_{GSS}	– –	10 1.0	nAdc μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (Note 2) (V_{DS} = -10 Vdc, V_{GS} = 0)	2N3909 2N3909A	I_{DSS}	0.3 1.0	15 15	mAdc
Gate-Source Voltage (V_{DS} = -10 Vdc, I_D = 30 μAdc)		V_{GS}	0.3	7.9	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance (Note 2) (V_{DS} = -10 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N3909 2N3909A	$\lvert y_{fs} \rvert$	1000 2200	5000 5000	μmhos
(V_{DS} = -10 Vdc, V_{GS} = 0, f = 10 MHz)	2N3909 2N3909A		900 2000	– –	
Output Admittance (V_{DS} = -10 Vdc, V_{GS} = 0, f = 1.0 kHz)		$\lvert y_{os} \rvert$	–	100	μmhos
Input Capacitance (V_{DS} = -10 Vdc, V_{GS} = 0, f = 1.0 MHz)	2N3909 2N3909A	C_{iss}	– –	32 9.0	pF
Reverse Transfer Capacitance (V_{DS} = -10 Vdc, V_{GS} = 0, f = 1.0 MHz)	2N3909 2N3909A	C_{rss}	– –	16 3.0	pF

*Indicates JEDEC Registered Data.

Note 1: The fourth lead (case) is connected to the source for all measurements.
Note 2: Pulse Test: Pulse Width ≤ 630 ms, Duty Cycle ≤ 10%.

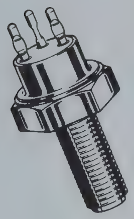
2N3924 (SILICON)
thru
2N3927

NPN silicon annular RF power transistors, optimized for large-signal power-amplifier and driver applications to 300 MHz.



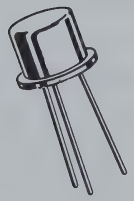
Collector electrically connected
to case; stud electrically
isolated from case

CASE 24
2N3925
(TO-102)



CASE 36
2N3926
2N3927
(TO-60)

Stud and case electrically
connected to emitter



CASE 79
2N3924
(TO-39)

Collector connected to case

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

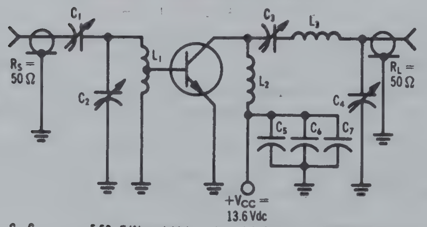
Rating	Symbol	2N3924	2N3925	2N3926	2N3927	Unit
Collector-Emitter Voltage	V_{CEO}	18	18	18	18	Vdc
Collector-Base Voltage	V_{CB}	36	36	36	36	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	4.0	4.0	Vdc
Collector Current	I_C	0.5	1.0	1.5	3.0	Adc
Power Dissipation @ T_C = 25°C Derate above 25°C	P_D	7.0 40	10 57.1	11.6 66.3	23.2 132.5	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →				°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage (1)	I_C = 200 mAdc	$BV_{CEO(sus)}$	18	-	-	Vdc
Collector-Base Breakdown Voltage	I_C = 0.25 mAdc, I_E = 0 2N3924 thru 2N3926	BV_{CBO}	36	-	-	Vdc
	I_C = 0.50 mAdc, I_E = 0 2N3927		36	-	-	
Emitter-Base Breakdown Voltage	I_E = 1.0 mAdc, I_C = 0 2N3924 thru 2N3926	BV_{EBO}	4.0	-	-	Vdc
	I_E = 2.0 mAdc, I_C = 0 2N3927		4.0	-	-	
Collector Cutoff Current	V_{CB} = 15 Vdc, I_E = 0 2N3924 thru 2N3926 2N3927	I_{CBO}	-	-	0.1 0.25	mAdc
	V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C 2N3924 thru 2N3926		-	-	5.0	
	2N3927		-	-	10	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product	I_C = 100 mAdc, V_{CE} = 13.6 Vdc, f = 100 MHz 2N3924 thru 2N3926	f_T	-	350	-	MHz
	I_C = 200 mAdc, V_{CE} = 13.6 Vdc, f = 100 MHz 2N3927		-	350	-	
Output Capacitance	V_{CB} = 13.6 Vdc, I_E = 0, f = 100 kHz 2N3924 thru 2N3926	C_{ob}	-	12.5	20	pF
	2N3927		-	25	45	
FUNCTIONAL TESTS **2N3924**						
Power Input	Test Circuit Figure 1	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	6.0	7.3	-	dB
Collector Efficiency	P_{out} = 4.0 Watts	η	70	-	-	%
2N3925						
Power Input	Test Circuit Figure 1	P_{in}	-	-	1.3	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	5.84	6.5	-	dB
Collector Efficiency	P_{out} = 5.0 Watts	η	70	-	-	%
2N3926						
Power Input	Test Circuit Figure 1	P_{in}	-	-	2.0	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	5.44	6.0	-	dB
Collector Efficiency	P_{out} = 7.0 Watts	η	70	-	-	%
2N3927						
Power Input	Test Circuit Figure 1	P_{in}	-	-	4.0	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	4.77	5.0	-	dB
Collector Efficiency	P_{out} = 12 Watts	η	80	-	-	%

(1) Pulsed thru a 25-mH inductor (See Figure 2)

FIGURE 1 — 175 MHz TEST CIRCUIT


C1
C3
L3
RS = 50 Ω
L1
C2
L2
C4
RL = 50 Ω
C5
C6
C7
+VCC = 13.6 Vdc

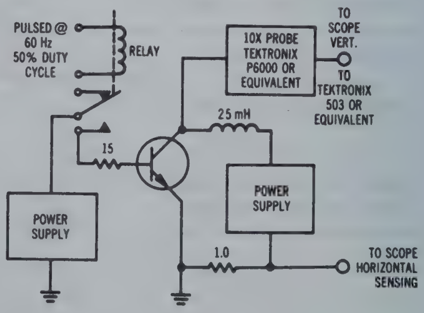
Part	Value
C_1, C_2, C_4	5-50 pF (Air variable)
C_3	7-100 pF (Air variable)
C_5	470 pF (Disc ceramic)
C_6	0.01 μF (Disc ceramic)
C_7	0.001 μF (Disc ceramic)

L_1 — 1 1/2 turns #14 AWG tinned wire; 3/8" ID Air wound; winding length 3/16"; base tapped 1 turn from ground

L_2 — RFC

L_3 — 2 turns #14 AWG tinned wire; 1/4" ID Air wound; winding length 3/16"

FIGURE 2 — PULSE TEST CIRCUIT


PULSED @ 60 Hz 50% DUTY CYCLE
RELAY
10X PROBE TEKTRONIX P6000 OR EQUIVALENT
TO SCOPE VERT.
TO TEKTRONIX 503 OR EQUIVALENT
25 mH
15
POWER SUPPLY
POWER SUPPLY
1.0
TO SCOPE HORIZONTAL SENSING

CLASS C DESIGN DATA FOR $V_{CE} = 13.6$ Vdc, $T_C = 25°C$

(Emitter Grounded Directly to the Chassis — No Tuned-Emitter Techniques Used)

2N3924

FIGURE 3 — POWER OUTPUT vs FREQUENCY

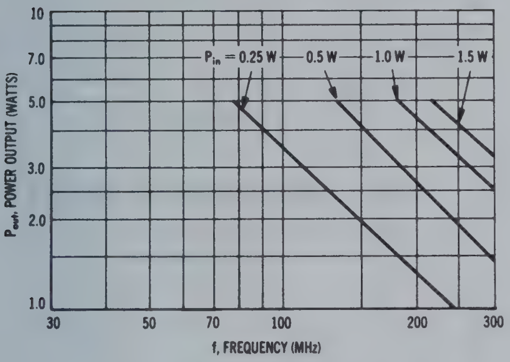


FIGURE 4 — POWER OUTPUT vs POWER INPUT

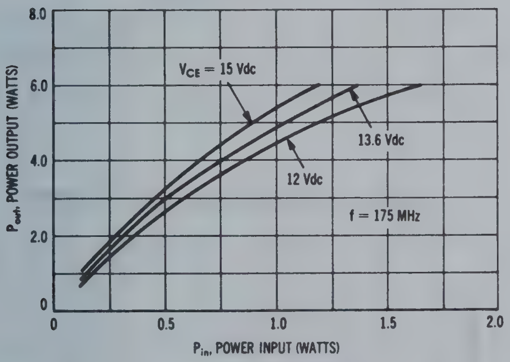


FIGURE 5 — PARALLEL EQUIVALENT INPUT RESISTANCE

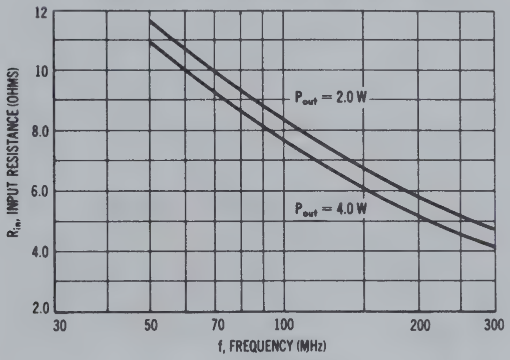


FIGURE 6 — PARALLEL EQUIVALENT INPUT CAPACITANCE

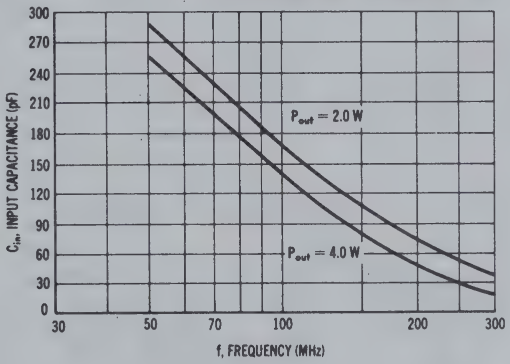
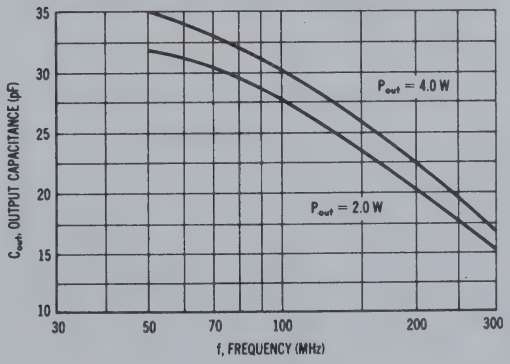


FIGURE 7 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3925

FIGURE 8 — POWER OUTPUT vs FREQUENCY

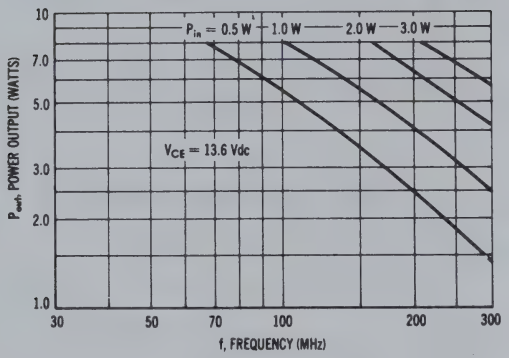


FIGURE 9 — POWER OUTPUT vs POWER INPUT

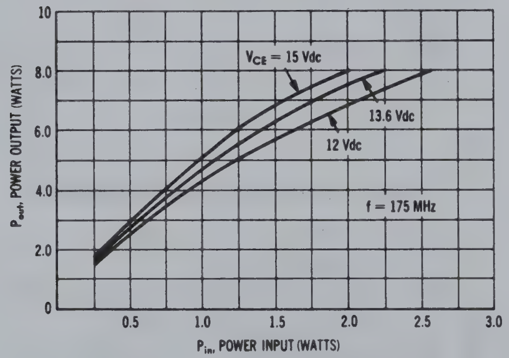


FIGURE 10 — PARALLEL EQUIVALENT INPUT RESISTANCE

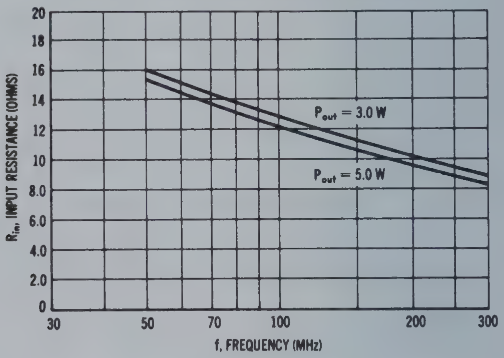


FIGURE 11 — PARALLEL EQUIVALENT INPUT CAPACITANCE

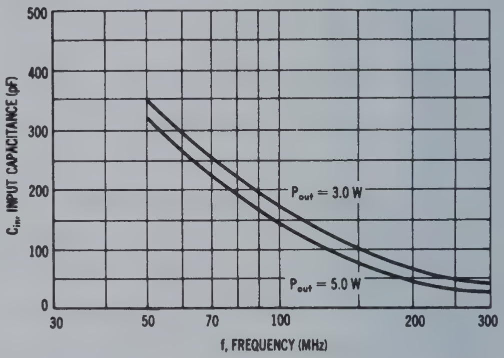
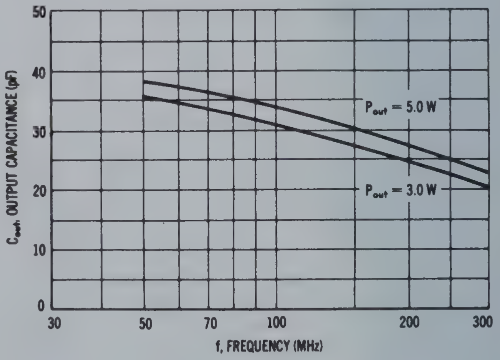


FIGURE 12 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3926

FIGURE 15 — PARALLEL EQUIVALENT INPUT RESISTANCE

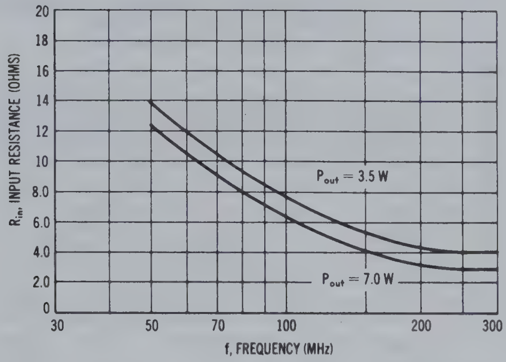


FIGURE 13 — POWER OUTPUT vs FREQUENCY

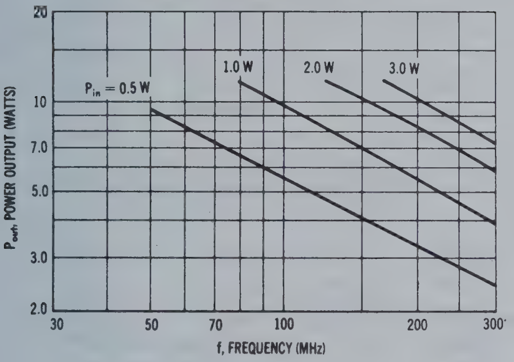


FIGURE 16 — PARALLEL EQUIVALENT INPUT CAPACITANCE

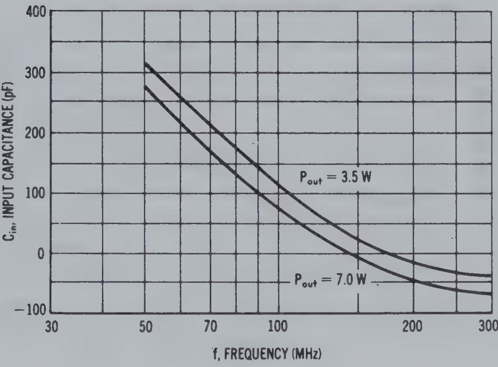


FIGURE 14 — POWER OUTPUT vs POWER INPUT

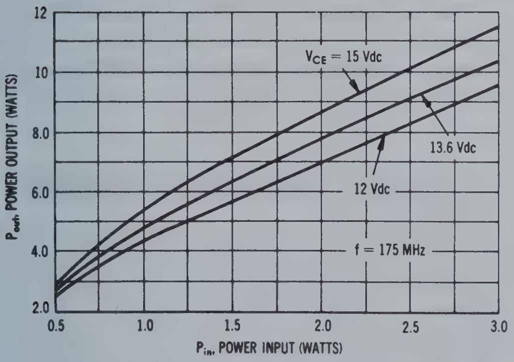
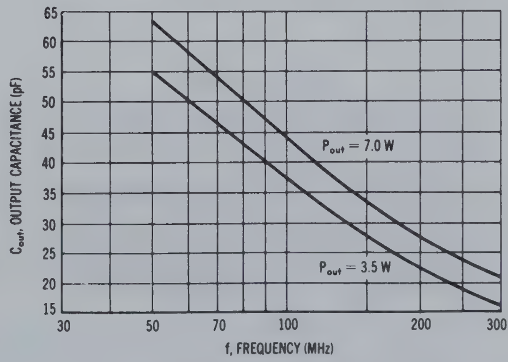


FIGURE 17 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3927

FIGURE 18 — POWER INPUT vs FREQUENCY

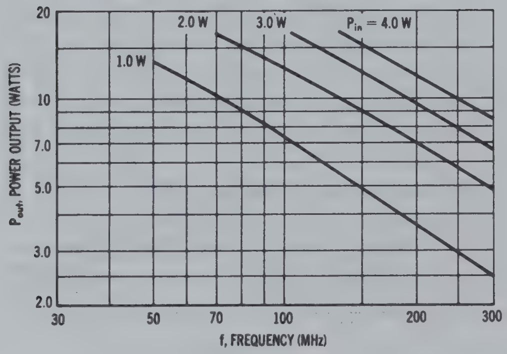
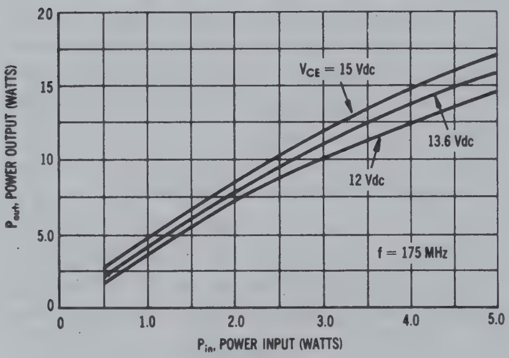


FIGURE 19 — POWER OUTPUT vs POWER INPUT



DESIGN NOTE

For Class C power-amplifier designs, small-signal parameters are not applicable. The parallel equivalent output capacitance and input resistance and capacitance for Class C power-amplifier design are used.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data for Class C design to complete device impedance data.

FIGURE 20 — PARALLEL EQUIVALENT INPUT RESISTANCE

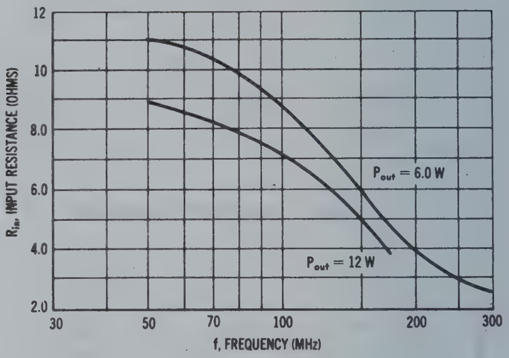


FIGURE 21 — PARALLEL EQUIVALENT INPUT CAPACITANCE

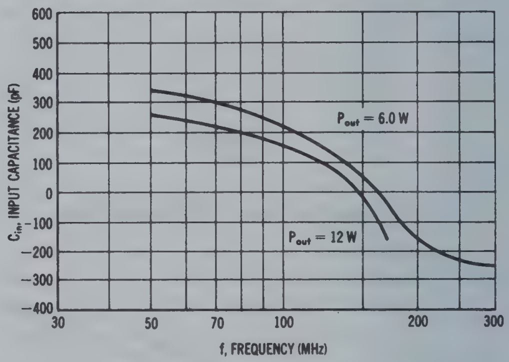
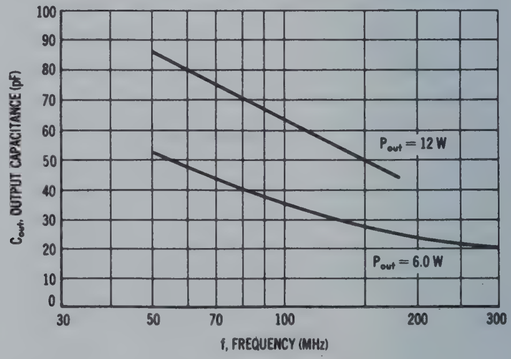
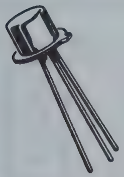


FIGURE 22 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3946 (SILICON)
2N3947



CASE 22
(TO-18)

Collector connected to case

NPN silicon annular transistors, designed for general purpose switching and amplifier applications. The 2N3946 and 2N3947 are complementary with PNP types 2N3250 and 2N3251, respectively.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	1.2 6.9	Watts mW/°C
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	0.36 2.06	Watt mW/°C
Thermal Resistance Junction to Ambient Junction to Case	 θ_{JA} θ_{JC}	 0.49 0.15	 °C/mW °C/mW
Junction Operating Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)	BV_{CEO}*	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc) (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc, T_A = 150°C)	I_{CEX}	 — —	 .010 15	μAdc
Base Cutoff Current (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc)	I_{BL}	—	.025	μAdc

*Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2% V_{OB} = Base-Emitter Reverse Bias

ELECTRICAL CHARACTERISTICS (continued)

(T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain[1]		h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc)	2N3946		30	—	
	2N3947		60	—	
(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)	2N3946		45	—	
	2N3947		90	—	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3946		50	150	
	2N3947		100	300	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N3946		20	—	
	2N3947		40	—	
Collector Saturation Voltage[1]		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.2	
(I_C = 50 mAdc, I_B = 5 mAdc)			—	0.3	
Base-Emitter Saturation Voltage[1]		$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			0.6	0.9	
(I_C = 50 mAdc, I_B = 5 mAdc)			—	1.0	
TRANSIENT CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	4.0	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	8.0	pF
Current-Gain - Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3946	f_T	250	—	MHz
	2N3947		300	—	
Delay Time	V_{CC} = 3 Vdc, V_{OB} = 0.5 Vdc I_C = 10 mAdc, I_{B1} = 1 mA	t_d	—	35	ns
Rise Time		t_r	—	35	ns
Storage Time	V_{CC} = 3 V, I_C = 10 mA, I_{B1} = $-I_{B2}$ = 1 mAdc 2N3946	t_s	—	300	ns
	2N3947		—	375	
Fall Time		t_f	—	75	ns
SMALL SIGNAL CHARACTERISTICS					
Small-Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3946	h_{fe}	50	250	—
	2N3947		100	700	
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3946	h_{re}	—	10	$X10^{-4}$
	2N3947		—	20	
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3946	h_{ie}	0.5	6.0	kohms
	2N3947		2.0	12	
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3946	h_{oe}	1.0	30	µmhos
	2N3947		5.0	50	
Collector-Base Time Constant (I_C = 10 mA, V_{CE} = 20 V, f = 31.8 MHz)		r'_bC_C	—	200	ps
Wide Band Noise Figure (I_C = 100 µA, V_{CE} = 5 V, R_g = 1 kΩ, f = 10 Hz to 15.7 kHz)		NF	—	5.0	dB

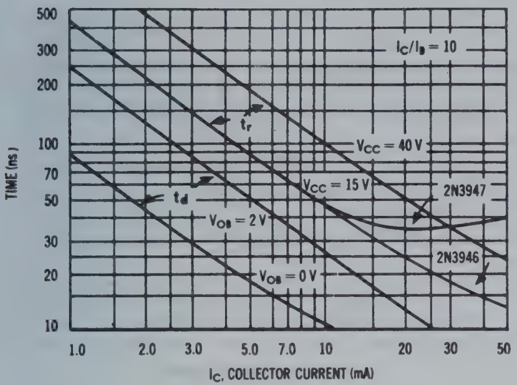
(1)Pulse Test: PW ≤ 300 µs, Duty Cycle ≤ 2%

V_{OB} = Base-Emitter Reverse Bias

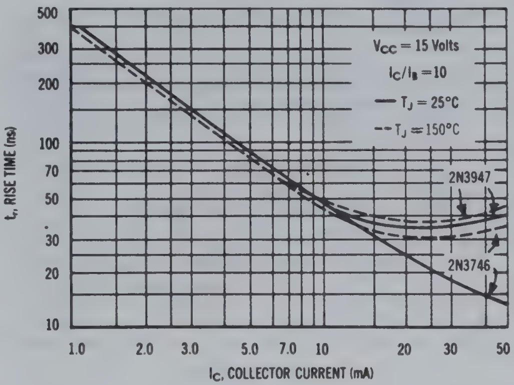
TYPICAL SWITCHING CHARACTERISTICS

(T_A = 25°C unless otherwise noted)

DELAY AND RISE TIME

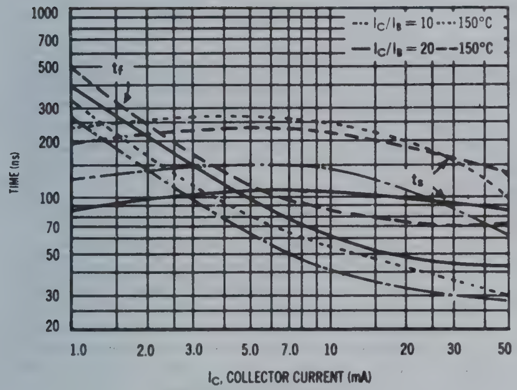


RISE TIME

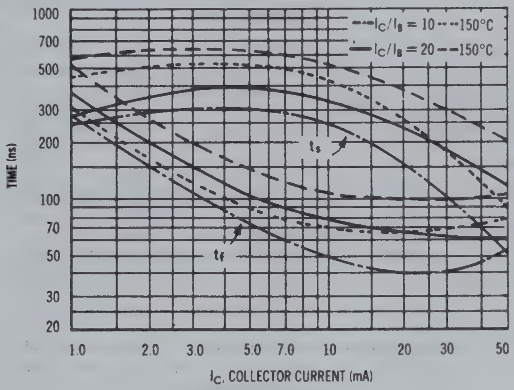


STORAGE AND FALL TIMES

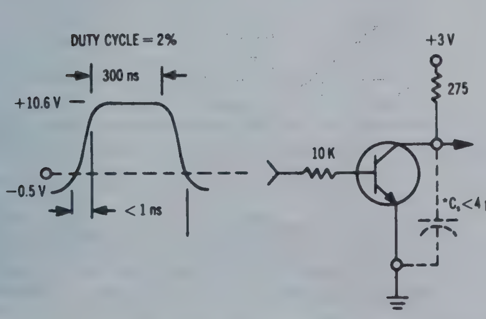
2N3946



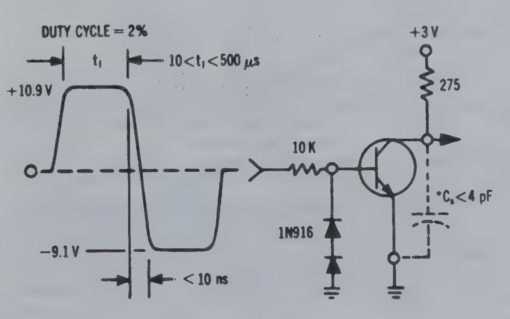
2N3947



TURN-ON TIME EQUIVALENT TEST CIRCUIT


DUTY CYCLE = 2%
300 ns
+10.6 V
−0.5 V
< 1 ns
+3 V
275
10 K
*C_s < 4 pF

TURN-OFF TIME EQUIVALENT TEST CIRCUIT

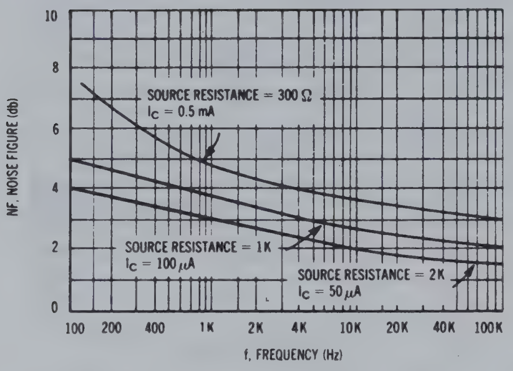

DUTY CYCLE = 2%
t_1
10 < t_1 < 500 μs
+10.9 V
−9.1 V
< 10 ns
+3 V
275
10 K
1N916
*C_s < 4 pF

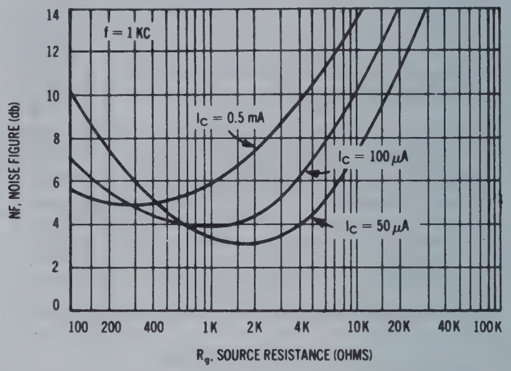
*TOTAL SHUNT CAPACITANCE OF TEST JIG AND CONNECTORS

AUDIO SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

V_{CE} = 5 V, T_A = 25°C

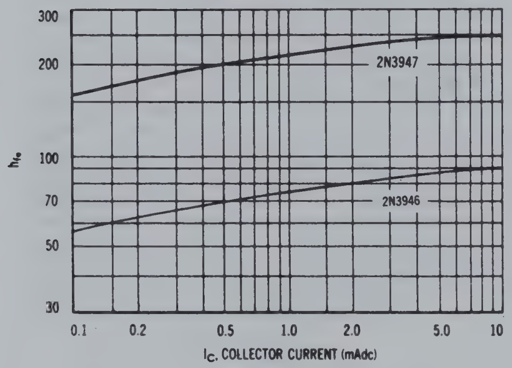




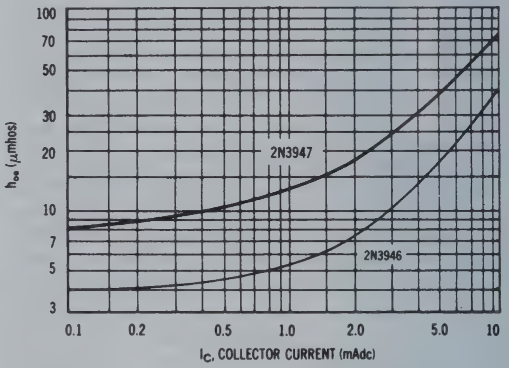
h PARAMETERS

V_{CE} = 10 V, T_A = 25°C, f = 1 Kc

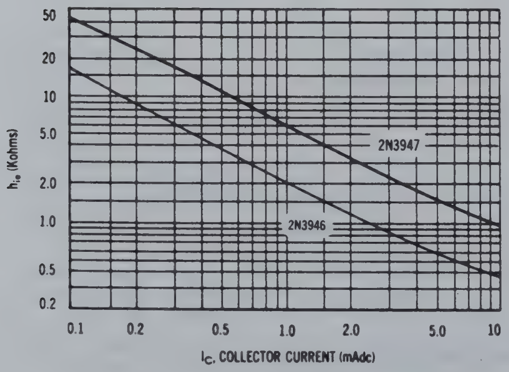
CURRENT GAIN



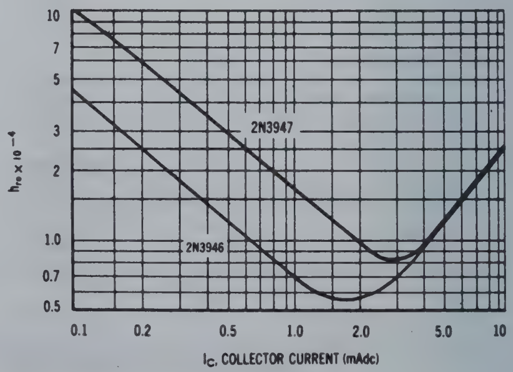
OUTPUT ADMITTANCE



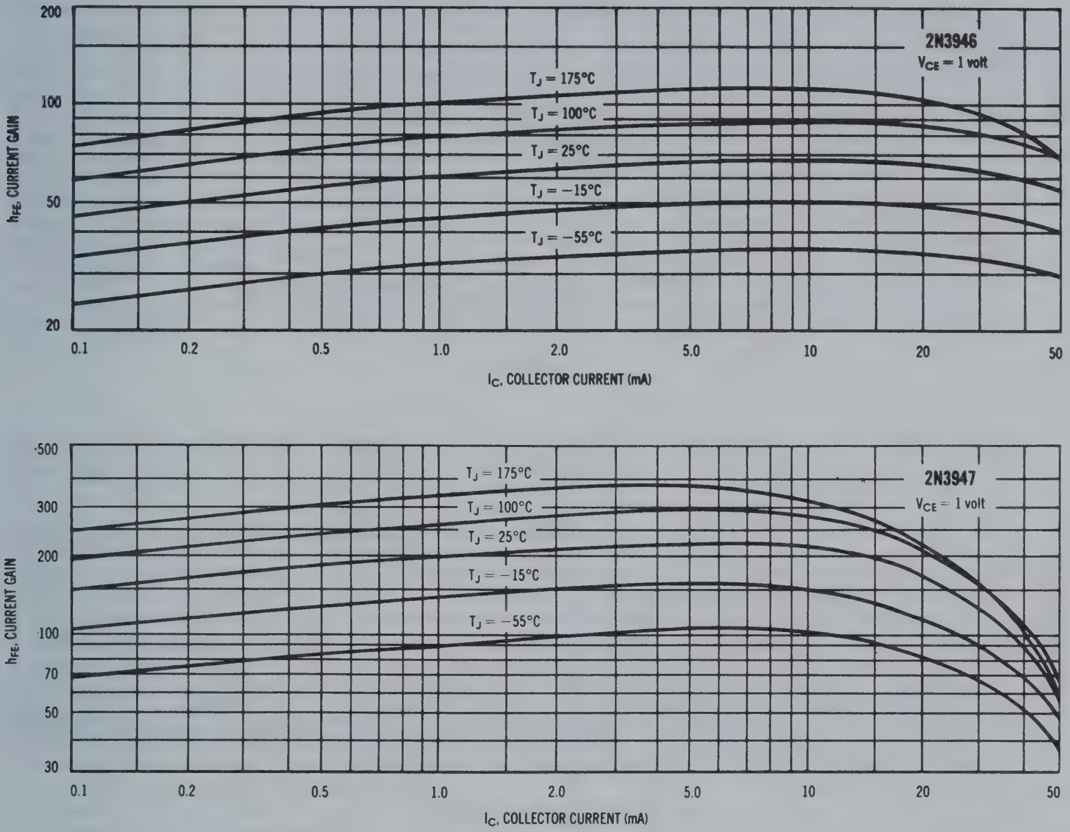
INPUT IMPEDANCE



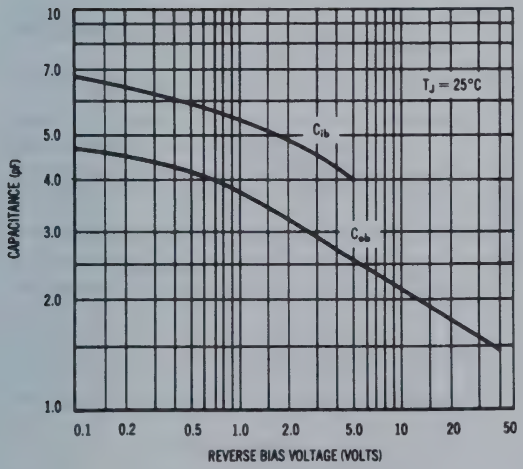
VOLTAGE FEEDBACK RATIO



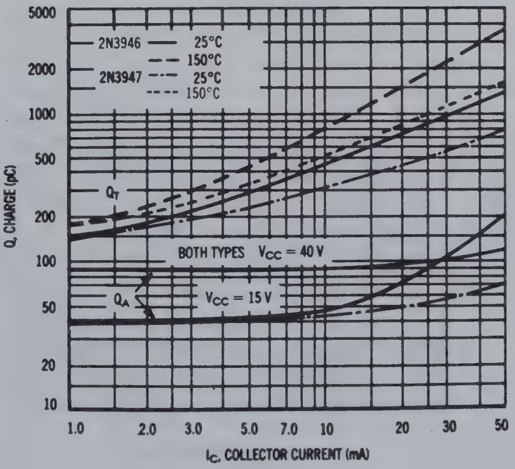
CURRENT GAIN CHARACTERISTICS



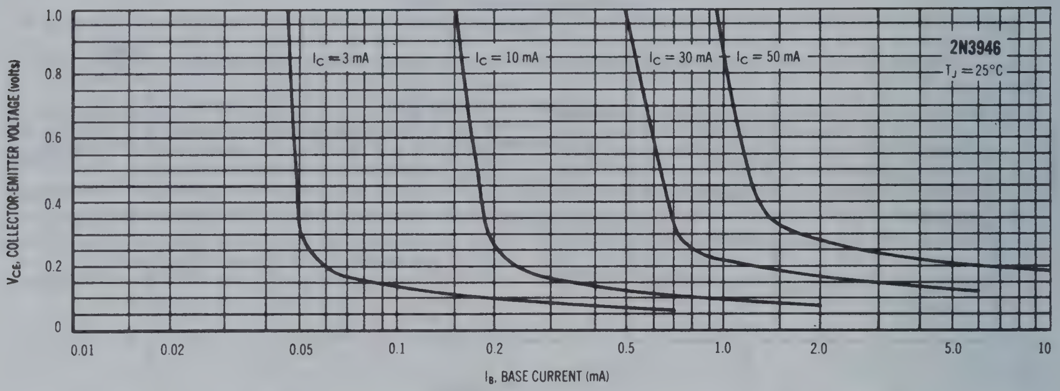
CAPACITANCE

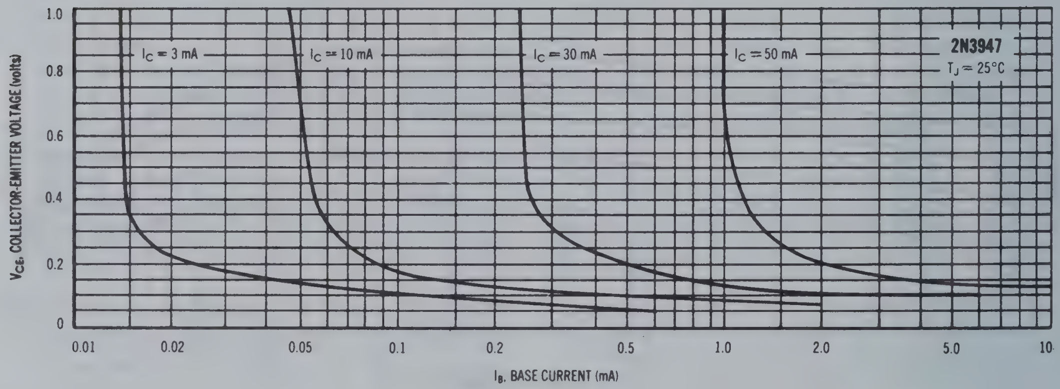


CHARGE DATA

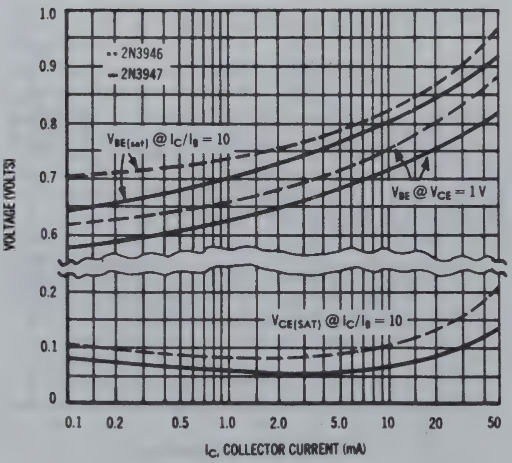


COLLECTOR SATURATION REGION

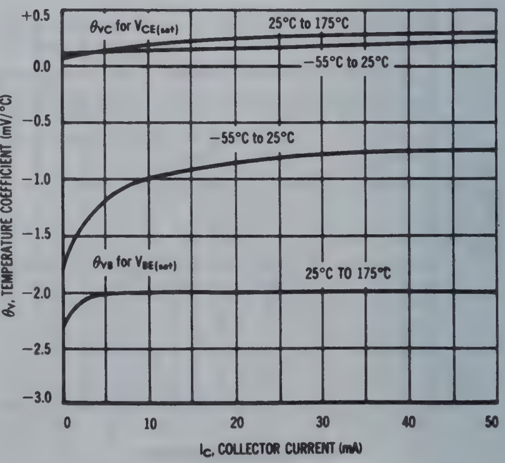




"ON" VOLTAGES



TEMPERATURE COEFFICIENTS



2N3948 (SILICON)

NPN silicon RF power transistor designed for amplifier, frequency multiplier, or oscillator applications in military and industrial equipment. Suitable for use as output, driver, or pre-driver stages in VHF and UHF equipment. Ideal for CATV applications.

CASE 79
(TO-39)

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	36	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current — Continuous	I_C	400	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	175	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 5 mAdc, I_B = 0)	$BV_{CEO(sus)}$	20	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	36	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	3.5	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.1 100	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 50 mAdc, V_{CE} = 5 Vdc)	h_{FE}	15	—	—
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_E = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	f_T	700	—	MHz
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	4.5	pF
FUNCTIONAL TEST				
Power Gain V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 400 MHz, P_{in} = 0.25 W	G_{PE}	6.0	—	dB
Power Output	P_{out}	1.0	—	Watt
Collector Efficiency	η	45	—	%

SMALL-SIGNAL ADMITTANCE PARAMETERS VERSUS FREQUENCY

(I_C = 80 mAdc, V_{CE} = 15 Vdc, T_A = 25°C)

FIGURE 1 — y_{ie}

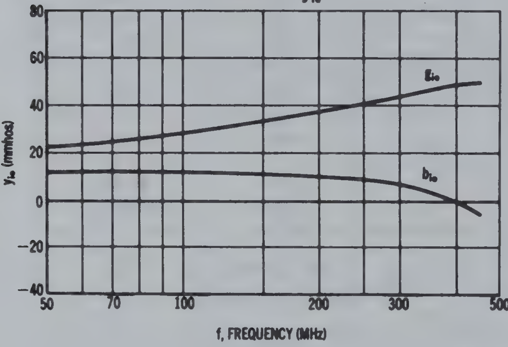


FIGURE 2 — y_{re}

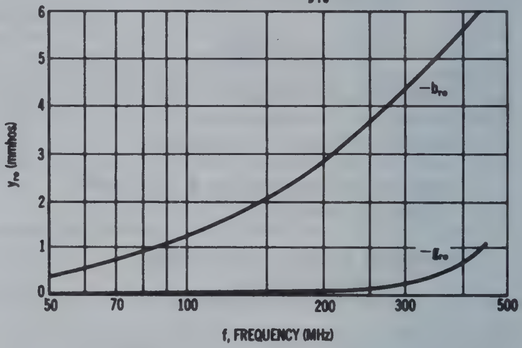


FIGURE 3 — y_{fe}

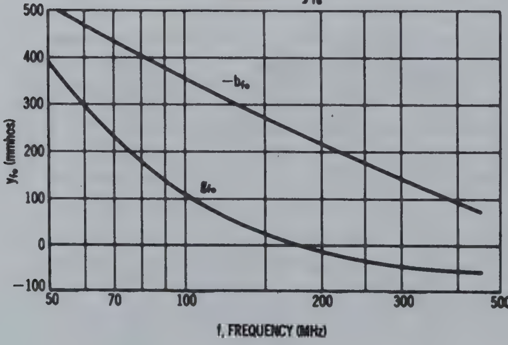


FIGURE 4 — y_{oe}

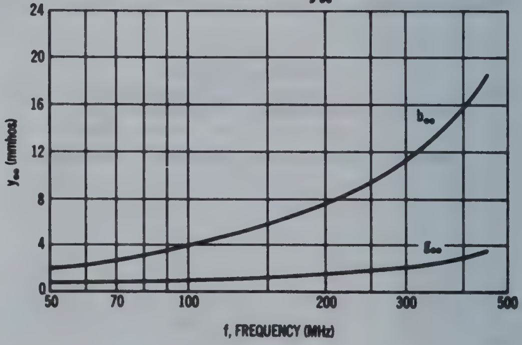


FIGURE 5 — SMALL-SIGNAL CURRENT GAIN

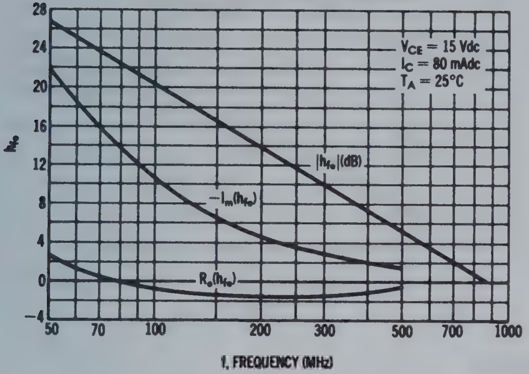
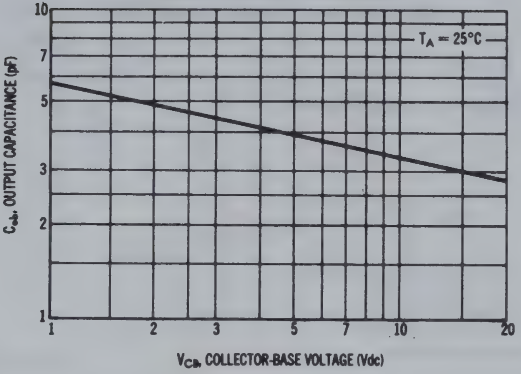


FIGURE 6 — OUTPUT CAPACITANCE



SMALL-SIGNAL ADMITTANCE PARAMETERS VERSUS COLLECTOR CURRENT

(f = 200 MHz, T_A = 25°C)

— V_{CE} = 10 V   — V_{CE} = 15 V

FIGURE 7 — y_{ie}

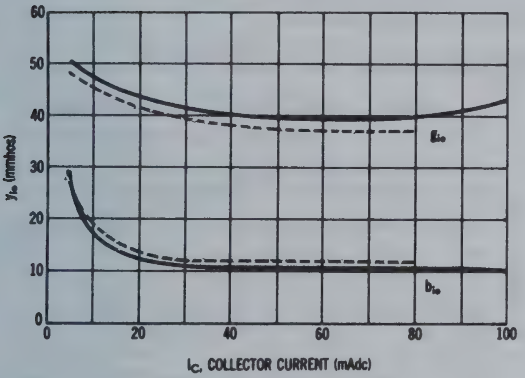


FIGURE 8 — y_{re}

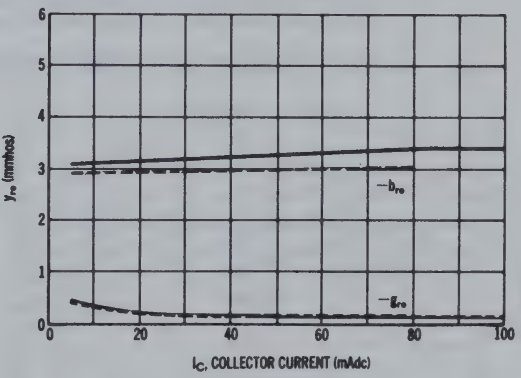


FIGURE 9 — y_{fe}

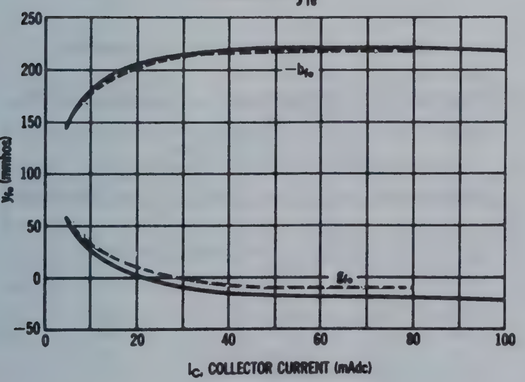


FIGURE 10 — y_{oe}

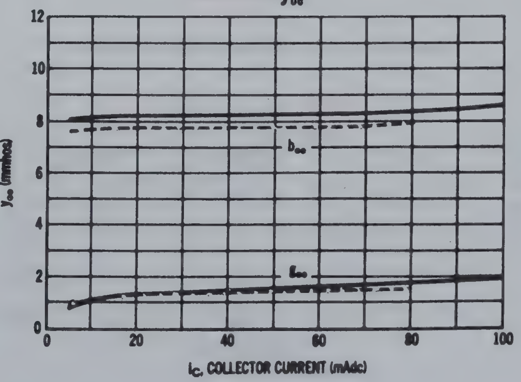
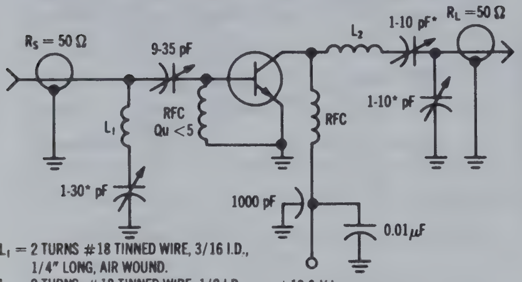
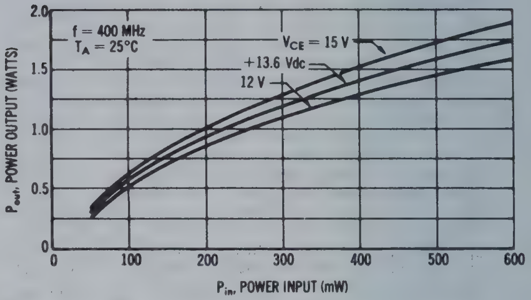


FIGURE 11 — 400 MHz RF AMPLIFIER TEST CIRCUIT



L_1 = 2 TURNS #18 TINNED WIRE, 3/16 I.D., 1/4″ LONG, AIR WOUND.
L_2 = 2 TURNS, #18 TINNED WIRE, 1/2 I.D., 3/16″ LONG, AIR WOUND.
*AIR VARIABLE CAPACITORS

FIGURE 12 — POWER GAIN



DESIGN NOTE

Figures 1 through 4 and 7 through 10 show small-signal admittance-parameter data. This data can be used for Class A amplifier designs.

For Class C power-amplifier designs, the small-signal parameters are not applicable. The parallel equivalent output capacitance and input resistance and capacitance for Class C power-amplifier operation are used

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data in Figures 14, 15 and 16 to comprise complete device impedance data for Class C power amplifier design.

CLASS C DESIGN DATA (EMITTER GROUNDED DIRECTLY TO CHASSIS)

(V_{CE} = 13.6 V, T_A = 25°C)

FIGURE 13 — POWER OUTPUT

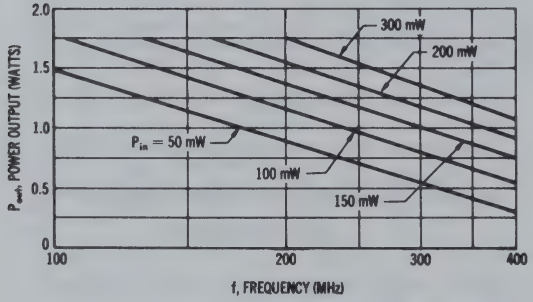


FIGURE 14 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

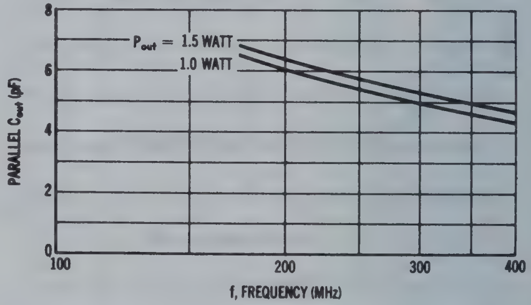


FIGURE 15 — PARALLEL EQUIVALENT INPUT RESISTANCE

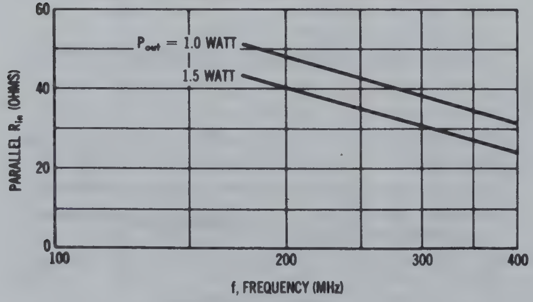
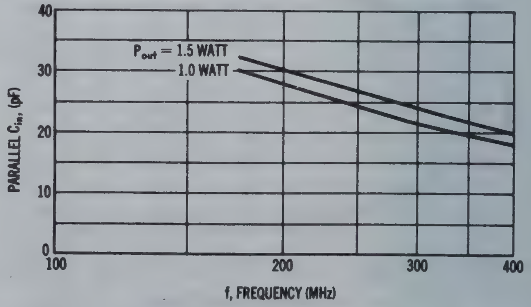


FIGURE 16 — PARALLEL EQUIVALENT INPUT CAPACITANCE



2N3950 (SILICON)

NPN silicon RF power transistor designed for high-power RF amplifier applications in military and industrial equipment.

CASE 36
(TO-60)

Emitter common to stud and case

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector-Current — Continuous	I_C	3.3	Amp
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	2.8 16	Watts mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	70 0.4	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

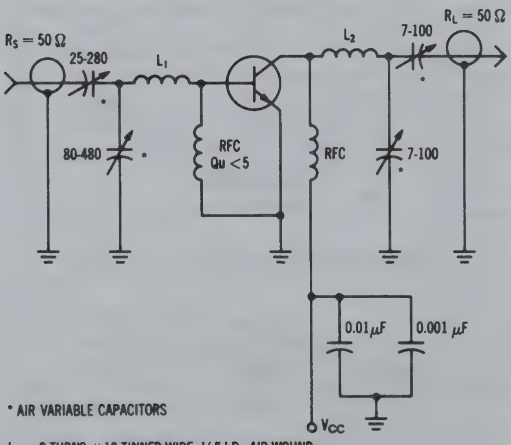
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	62.5	°C/W
Thermal Resistance, Junction to Case	θ_{JC}	2.5	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 200 mAdc, I_B = 0)	$BV_{CEO(sus)}$	35	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, V_{BE} = 0)	BV_{CES}	65	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 mAdc, I_C = 0)	BV_{EBO}	4.0	—	—	Vdc
Collector Cutoff Current (V_{CB} = 65 Vdc, I_E = 0) (V_{CB} = 28 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	— —	10 10	mAdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_E = 500 mAdc, V_{CE} = 28 Vdc, f = 50 MHz)	f_T	—	150	—	MHz
Output Capacitance (V_{CB} = 28 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	80	120	pF
FUNCTIONAL TEST					
Power Gain Test Circuit — Figure 1, P_{out} = 50 W, V_{CC} = 28 Vdc, R_S = 50 ohms, f = 50 MHz	G_{PE}	8.0	—	—	dB
Collector-Efficiency	η	60	—	—	%

(1) Pulsed through a 25 mH inductor; Duty factor = 50%, Rep. Rate ≤ 60 Hz.

FIGURE 1 — 50 MHz TEST CIRCUIT

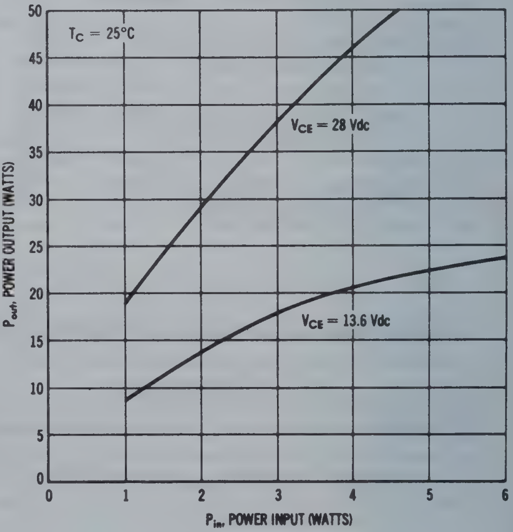


* AIR VARIABLE CAPACITORS

L_1 = 2 TURNS #18 TINNED WIRE, ¼″ I.D., AIR WOUND, WINDING LENGTH ⅛″.

L_2 = 5 TURNS #16 TINNED WIRE, ⅜″ I.D., AIR WOUND, WINDING LENGTH ¾″.

FIGURE 2 — 50 MHz POWER GAIN



CLASS C DESIGN DATA FOR $V_{CE} = 28$ Vdc, $T_C = 25°C$

(EMITTER GROUNDED DIRECTLY TO THE CHASSIS — NO TUNED-EMITTER TECHNIQUES USED)

FIGURE 3 — POWER OUTPUT

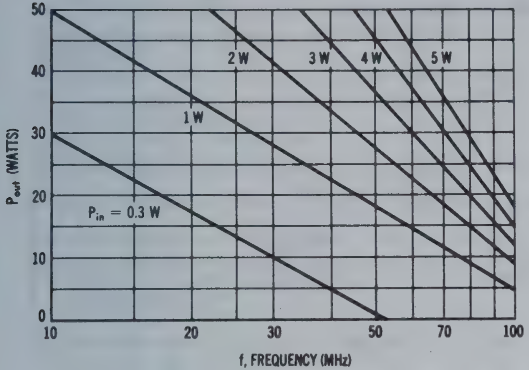


FIGURE 4 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

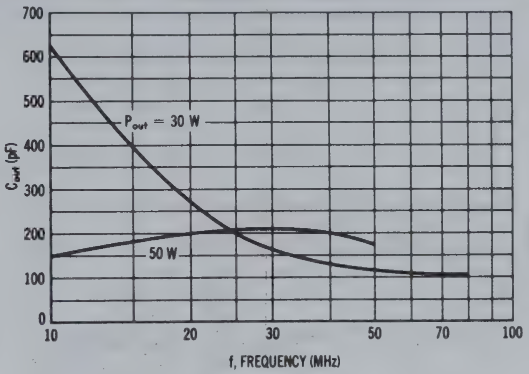


FIGURE 5 — PARALLEL EQUIVALENT INPUT RESISTANCE

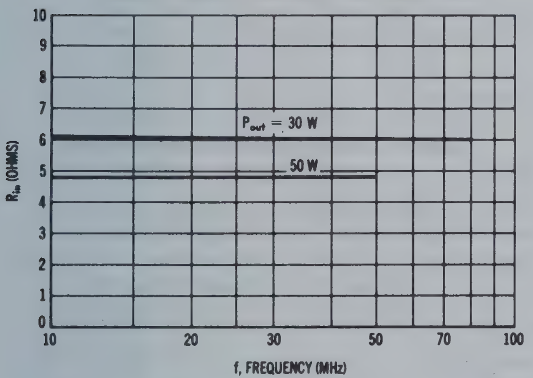
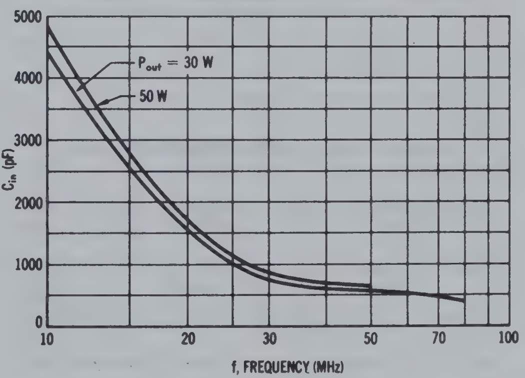


FIGURE 6 — PARALLEL EQUIVALENT INPUT CAPACITANCE



DESIGN NOTES

For Class-C power-amplifier designs, the small-signal parameters are not applicable. Figures 4 thru 6 and 8 thru 10 give the parallel equivalent output capacitance and input capacitance and resistance for Class-C power-amplifier operation.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L' may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data in Figures 4 through 10 to comprise complete device impedance data for Class-C power-amplifier design.

Due to the high performance capabilities of the 2N3950, care should be exercised during initial tuning of prototype circuits.

Input power should be increased gradually, while stopping at intermediate levels to tune. If tuning difficulties are experienced, or if the power or collector current are abnormal at any intermediate power input level, the difficulties should be resolved before increasing power levels further.

The 2N3950 is designed to provide maximum ruggedness commensurate with its high performance. Operation at loads with high SWR may produce dangerous voltage and current excursions, a condition which should be avoided. In addition, disconnecting the load at full power output could increase device dissipation to over 70 watts which could result in device failure due to dissipation beyond safe limits set by the junction to ambient thermal resistance, regardless of the internal construction and safe area of the device.

CLASS C DESIGN DATA FOR $V_{CE} = 13.6$ Vdc, $T_C = 25°C$

(EMITTER GROUNDED DIRECTLY TO THE CHASSIS — NO TUNED-EMITTER TECHNIQUES USED)

FIGURE 7 — POWER OUTPUT

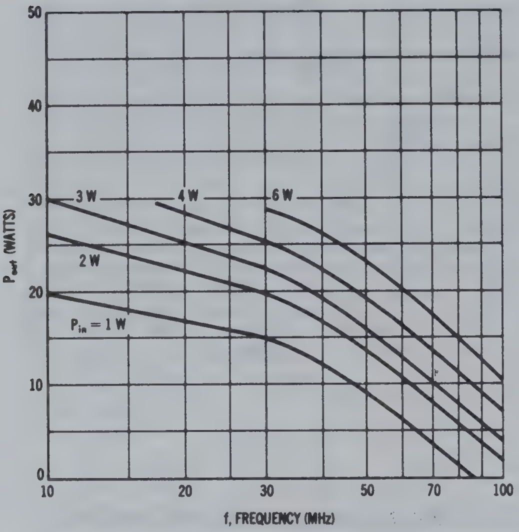


FIGURE 8 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

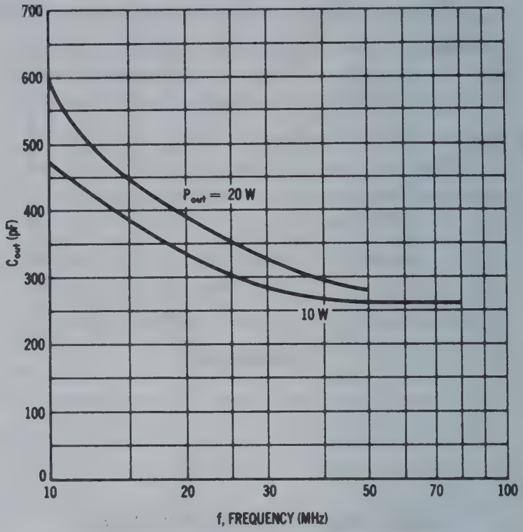


FIGURE 9 — PARALLEL EQUIVALENT INPUT RESISTANCE

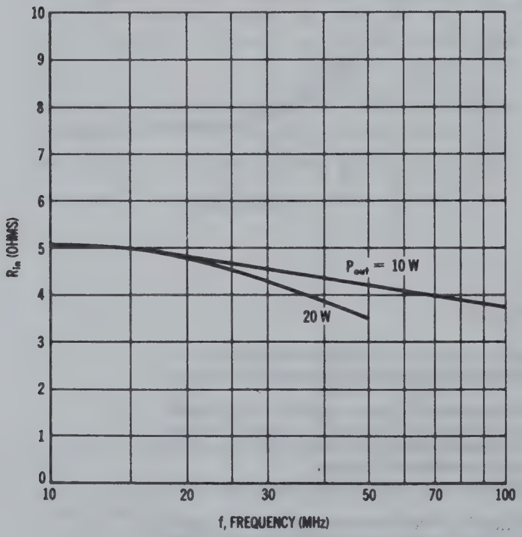
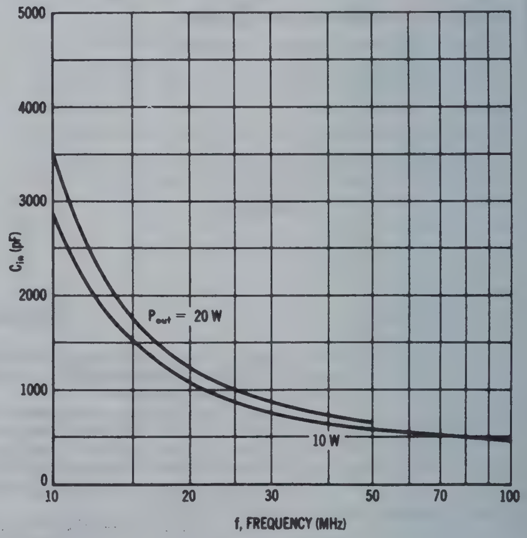


FIGURE 10 — PARALLEL EQUIVALENT INPUT CAPACITANCE



2N3959 (SILICON)
2N3960

CASE 22
(TO-18)

Collector connected to case

NPN silicon annular transistors particularly well suited for high-speed current-mode logic switching applications.

MAXIMUM RATINGS ($T_A = 25^oC$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage (1 to 30 mA)	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	750 4.3	mW mW/^oC
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	400 2.3	mW mW/^oC
Thermal Resistance Junction to Case Junction to Ambient	 θ_{JC} θ_{JA}	 0.233 0.436	^oC/mW
Junction Operating Temperature Range	T_J	200	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	20	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	—	Vdc
Collector Reverse Current (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc, T_A = 150°C)	9	I_{CEX}	 — —	 .005 5.0	μAdc
Base Cutoff Current (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc)	9	I_{BL}	—	.005	μAdc
Collector Forward Current (V_{CE} = 5 Vdc, V_{BE} = 0.4 Vdc)	9	I_{CEX}	—	1.0	μAdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
ON CHARACTERISTICS						
DC Current Gain		1	h_{FE}			—
(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)				25	—	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)				40	400	
(I_C = 30 mAdc, V_{CE} = 1 Vdc)				25	—	
Collector-Emitter Saturation Voltage		2, 3, 4	$V_{CE(sat)}$			Vdc
(I_C = 1.0 mAdc, I_B = 0.1 mAdc)				—	0.2	
(I_C = 30 mAdc, I_B = 3 mAdc)				—	0.3	
Base-Emitter "ON" Voltage		3,4	$V_{BE(ON)}$			Vdc
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)				—	0.8	
(I_C = 30 mAdc, V_{CE} = 1.0 Vdc)				—	1.0	
TRANSIENT CHARACTERISTICS						
Output Capacitance (V_{CB} = 4 Vdc, I_E = 0, f = 1 kHz)		8	C_{ob}	—	2.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		8	C_{ib}	—	2.5	pF
High-Frequency Current Gain			$\lvert h_{fe} \rvert$			—
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3959			13	—	
	2N3960			16	—	
Current-Gain - Bandwidth Product		5	f_T			MHz
(I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 100 MHz)	2N3959			1000	—	
	2N3960			1300	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3959			1300	—	
	2N3960			1600	—	
(I_C = 30 mAdc, V_{CE} = 4 Vdc, f = 100 MHz)	2N3959			1000	—	
	2N3960			1200	—	
Collector-Base Time Constant		6	$r'_b C_c$			ps
(I_C = 5 mAdc, V_{CE} = 4 Vdc)	2N3959			—	30	
	2N3960			—	50	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N3959			—	25	
	2N3960			—	40	
(I_C = 30 mAdc, V_{CE} = 4 Vdc)	2N3959			—	30	
	2N3960			—	50	

TYPICAL SWITCHING TIMES

				Typical Performance (v_{out} = 1 V)		
				@ 10 mA	@ 30 mA	
Turn-On Delay Time		7	$t_{on(delay)}$	2.4	2.0	ns
Rise Time	2N3959		t_r	3.0	2.2	ns
	2N3960			3.0	1.7	ns
Turn-Off Delay Time		7	$t_{off(delay)}$	1.6	1.6	ns
Fall-Time	2N3959		t_f	3.3	2.3	ns
	2N3960			3.3	1.9	ns

2N3959, 2N3960 (continued)

FIGURE 1

MINIMUM DC CURRENT GAIN

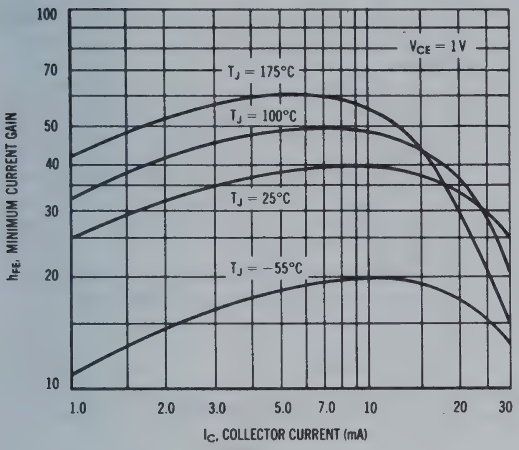
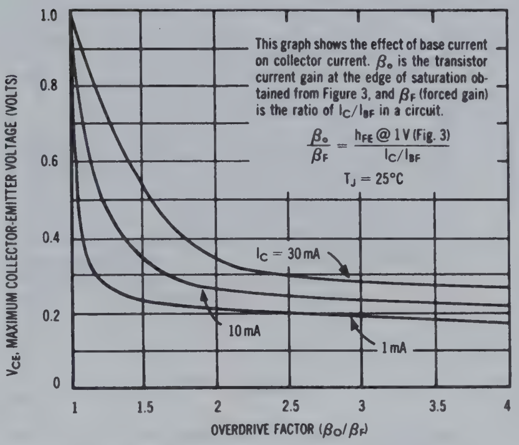


FIGURE 2

COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_o is the transistor current gain at the edge of saturation obtained from Figure 3, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

$$\frac{\beta_o}{\beta_F} = \frac{h_{FE} @ 1\,V \text{ (Fig. 3)}}{I_C/I_{BF}}$$

$T_J = 25°C$

FIGURE 3

"ON" VOLTAGE LIMITS

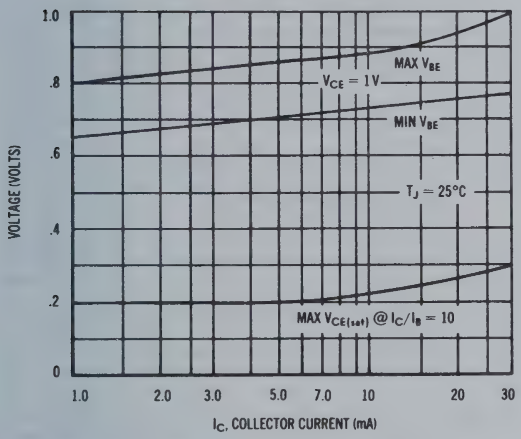


FIGURE 4

MAXIMUM COLLECTOR-BASE TIME CONSTANT

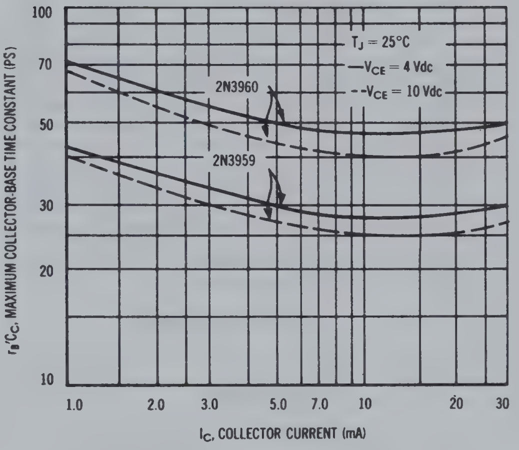


FIGURE 5

TYPICAL TEMPERATURE COEFFICIENTS

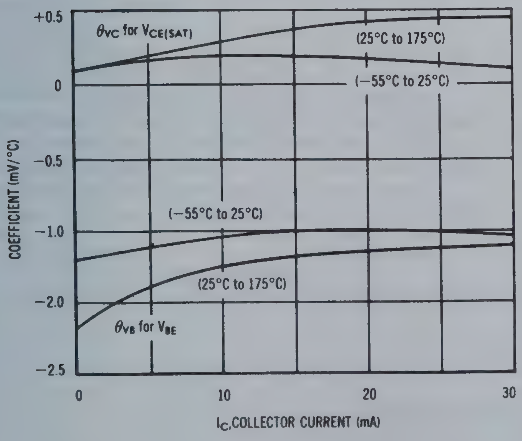


FIGURE 6

MINIMUM CURRENT GAIN-BANDWIDTH PRODUCT

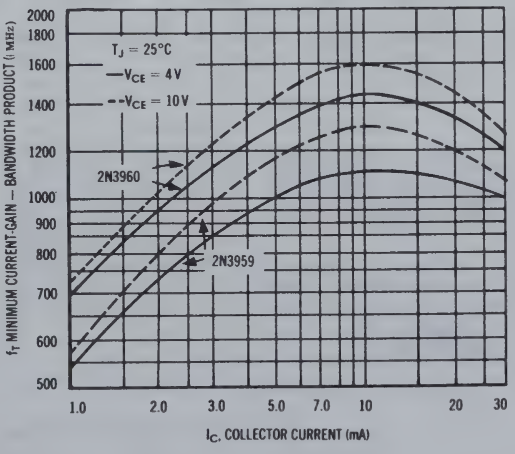


FIGURE 7

TYPICAL SWITCHING TIMES

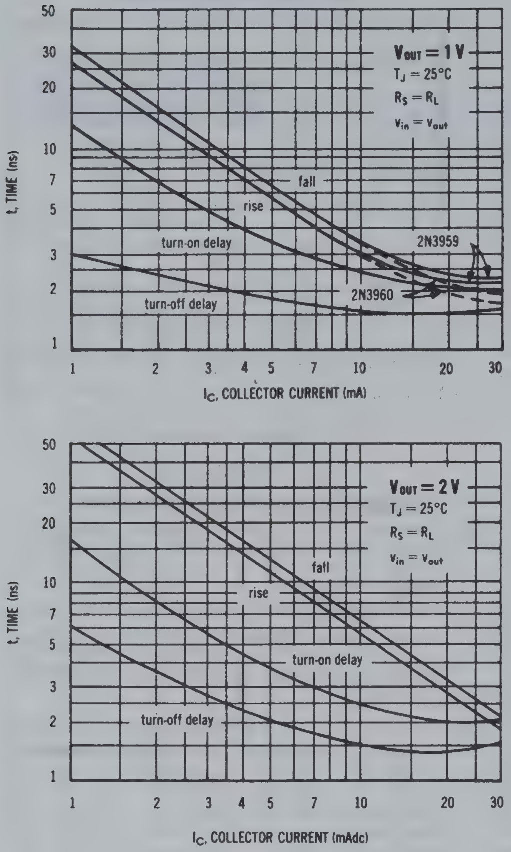


FIGURE 8

JUNCTION CAPACITANCE

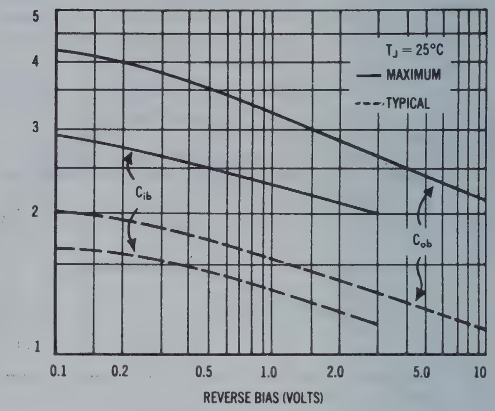
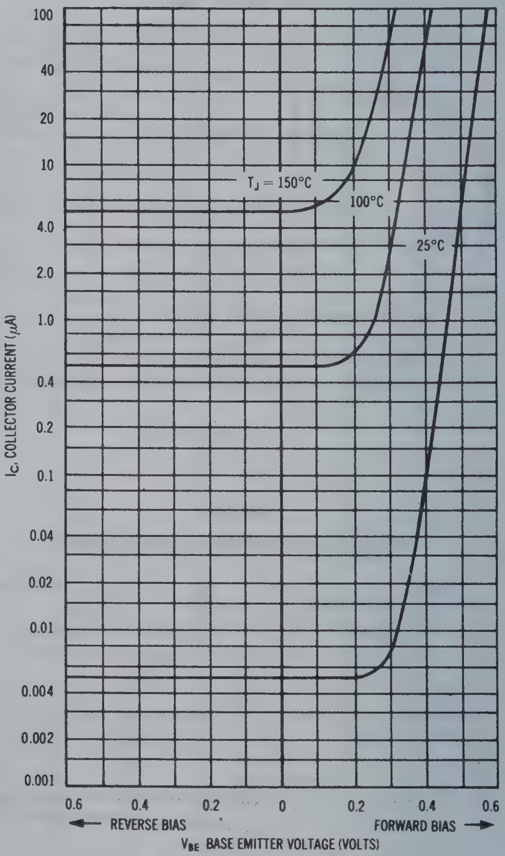
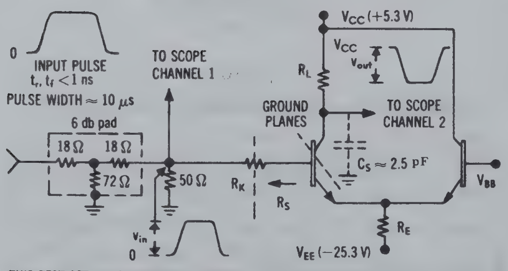


FIGURE 9

MAXIMUM CUT-OFF CHARACTERISTICS



TEST CIRCUIT



0
INPUT PULSE
t_r, t_f < 1 ns
PULSE WIDTH ≈ 10 μs
6 db pad
18 Ω
18 Ω
72 Ω
TO SCOPE CHANNEL 1
50 Ω
V_{in}
0
R_K
R_S
GROUND PLANES
V_{CC} (+5.3 V)
V_{CC}
V_{out}
R_L
TO SCOPE CHANNEL 2
$C_S \approx 2.5$ pF
R_E
V_{EE} (−25.3 V)
V_{BB}

THIS TEST SET UP IS DESIGNED TO SIMULATE A CASCADE OF IDENTICAL STAGES. ∴ THE SOURCE RESISTANCE (R_S) EQUALS THE LOAD RESISTANCE (R_L). VALUES USED IN THE TEST ARE SHOWN IN THE TABLE.

FOR $V_{in} = V_{out} = 1$V, $V_{BB} = +0.5$V, R_L & R_K VALUES APPROPRIATELY REDUCED

$V_{in} = V_{out} = 2$ volts, $V_{BB} = +1.0$V			
I_C (mA)	R_E (KΩ)	R_L (Ω)	R_K (Ω)
1.0	24.0	2 K	2 K
3.0	8.2	680	680
10	2.4	200	180
30	0.8	68	36

2N3961

For Specifications, See 2N3375 Data.

2N3970 (SILICON)
2N3971
2N3972

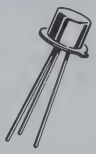
SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

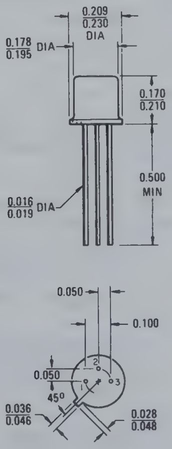
Depletion Mode (Type A) Junction Field-Effect Transistors designed primarily for chopper and high-speed switching applications.

- High Input Impedance —
  I_{GSS} = 250 pAdc (Max) @ V_{GS} = 20 Vdc
- Low Drain-Source "ON" Resistance —
  $r_{ds(on)}$ = 30 Ohms (Max) @ f = 1.0 kHz (2N3970)
- Guaranteed Switching Characteristics

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)




0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
2
1
3

Pin 1. Source
2. Drain
3. Gate and Case

CASE 22 (4)
TO-18

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	Vdc
Forward Gate Current	I_{GF}	50	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.

2N3970, 2N3971, 2N3972 (continued)

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{GS} = 0)		$V_{(BR)GSS}$	40	–	Vdc
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0)		I_{GSS}	–	250	pAdc
Drain Reverse Current		I_{DGO}			
(V_{DG} = 20 Vdc, I_S = 0)			–	250	pAdc
(V_{DG} = 20 Vdc, I_S = 0, T_A = 150°C)			–	500	nAdc
Drain Cutoff Current		$I_{D(off)}$			
(V_{DS} = 20 Vdc, V_{GS} = – 12 Vdc)			–	250	pAdc
(V_{DS} = 20 Vdc, V_{GS} = – 12 Vdc, T_A = 150°C)			–	500	nAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (Note 1)		I_{DSS}			mAdc
(V_{DS} = 20 Vdc, V_{GS} = 0)	2N3970		50	150	
	2N3971		25	75	
	2N3972		5.0	30	
Gate-Source Voltage		V_{GS}			Vdc
(V_{DS} = 20 Vdc, I_D = 1.0 nAdc)	2N3970		4.0	10	
	2N3971		2.0	5.0	
	2N3972		0.5	3.0	
Drain-Source "ON" Voltage		$V_{DS(on)}$			Vdc
(I_D = 20 mAdc, V_{GS} = 0)	2N3970		–	1.0	
(I_D = 10 mAdc, V_{GS} = 0)	2N3971		–	1.5	
(I_D = 5.0 mAdc, V_{GS} = 0)	2N3972		–	2.0	
Static Drain-Source "ON" Resistance		$r_{DS(on)}$			Ohms
(I_D = 1.0 mAdc, V_{GS} = 0)	2N3970		–	30	
	2N3971		–	60	
	2N3972		–	100	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance		$r_{ds(on)}$			Ohms
(V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N3970		–	30	
	2N3971		–	60	
	2N3972		–	100	
Input Capacitance (V_{DS} = 20 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	–	25	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = – 12 Vdc, f = 1.0 MHz)		C_{rss}	–	6.0	pF
SWITCHING CHARACTERISTICS					
Turn-On Delay Time Test Condition for 2N3970: (V_{DD} = 10 Vdc, $V_{GS(on)}$ = 0, $I_{D(on)}$ = 20 mAdc, $V_{GS(off)}$ = 10 Vdc)	2N3970	$t_{d(on)}$	–	10	ns
	2N3971		–	15	
	2N3972		–	40	
Rise Time Test Condition for 2N3971: (V_{DD} = 10 Vdc, $V_{GS(on)}$ = 0, $I_{D(on)}$ = 10 mAdc, $V_{GS(off)}$ = 5.0 Vdc)	2N3970	t_r	–	10	ns
	2N3971		–	15	
	2N3972		–	40	
Turn-Off Time Test Condition for 2N3972: (V_{DD} = 10 Vdc, $V_{GS(on)}$ = 0, $I_{D(on)}$ = 5.0 mAdc, $V_{GS(off)}$ = 3.0 Vdc)	2N3970	t_{off}	–	30	ns
	2N3971		–	60	
	2N3972		–	100	

*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width = 300 μs, Duty Cycle = 3.0%.

2N3980 (SILICON)

CASE 22 A
(TO-18 Modified)
(Lead 3 connected to case)

Silicon annular PN unijunction transistor designed for military and industrial use in pulse, timing, sensing, and oscillator circuits.

MAXIMUM RATINGS ($T_A = 25^{o}C$ unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	360*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	1.0**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage	V_{B2B1}	35	Volts
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 2.4 mW/°C increase in ambient temperature. Total power dissipation (available power to Emitter and Base-Two) must be limited by external circuitry.

**Capacitance discharge current must fall to 0.37 Amp within 3.0 ms and PRR $\leq$ 10 PPS.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) Note 1	η	0.68	—	0.82	—
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	R_{BB}	4.0	6.0	8.0	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65°C to +100°C)	αR_{BB}	0.4	—	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) Note 2	$V_{EB1(sat)}$	—	2.5	3.0	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)	$I_{B2(mod)}$	12	15	—	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0) (V_{B2E} = 30 V, I_{B1} = 0, T_A = 125°C)	I_{EO}	— —	5.0 —	10 1.0	nA µA
Peak Point Emitter Current (V_{B2B1} = 25 V)	I_P	—	0.6	2.0	µA
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) Note 2	I_V	1.0	4.0	10	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3)	V_{OB1}	6.0	8.0	—	Volts
Maximum Oscillation Frequency (Figure 4)	f(max)	1.0	1.25	—	MHz

NOTES

1. Intrinsic standoff ratio,
η,is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop
(≈0.5 V @ 10 µA)

2. Use pulse techniques: PW ≈ 300 µs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

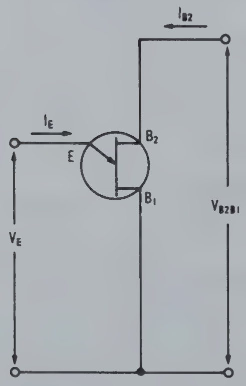


FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

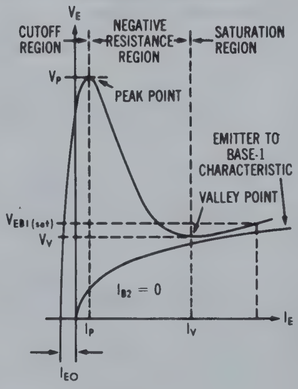


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

(Exaggerated to Show Details)

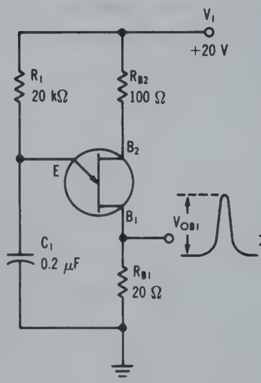


FIGURE 3 — V_{OB1} TEST CIRCUIT

(Typical Relaxation Oscillator)

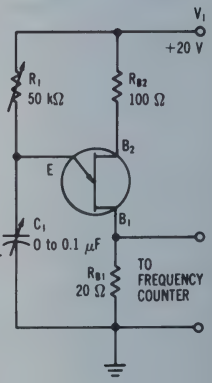


FIGURE 4 — F(max) MAXIMUM FREQUENCY TEST CIRCUIT

2N3993, 2N3994 (SILICON)
2N3994A

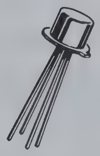
SILICON P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

Depletion Mode (Type A) Junction Field-Effect Transistors designed primarily for chopper and high-speed switching applications.

- Low Leakage Current —
  I_{DGO} = 1.2 nAdc (Max) @ V_{DG} = 15 Vdc
- Low Reverse Transfer Capacitance —
  C_{rss} = 4.5 pF (Max) @ V_{GS} = 10 Vdc (2N3993)
- Low Drain-Source "ON" Resistance —
  $r_{ds(on)}$ = 150 Ohms (Max) @ f = 1.0 kHz (2N3993)

P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

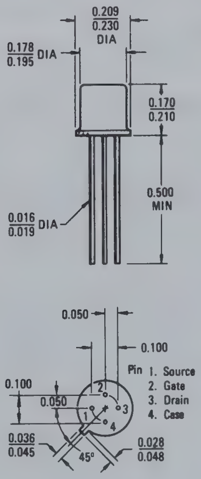
(Type A)



*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-25	Vdc
Drain-Gate Voltage	V_{DG}	-25	Vdc
Reverse Gate-Source Voltage	V_{GSR}	25	Vdc
Forward Gate Current	I_{GF}	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
0.100
Pin 1. Source
2. Gate
3. Drain
4. Case
0.100
0.050
1
2
3
4
0.036
0.045
45°
0.028
0.048

TO-72
CASE 20 (5)

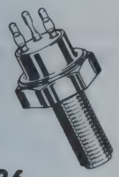
2N3993, 2N3994, 2N3994A (continued)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	25	–	Vdc
Drain Reverse Current		I_{DGO}			
(V_{DG} = –15 Vdc, I_S = 0)			–	1.2	nAdc
(V_{DG} = –15 Vdc, I_S = 0, T_A = 150°C)			–	1.2	μAdc
Drain Cutoff Current		$I_{D(off)}$			
(V_{DS} = –10 Vdc, V_{GS} = 10 Vdc)	2N3993		–	1.2	nAdc
(V_{DS} = –10 Vdc, V_{GS} = 6.0 Vdc)	2N3994, 2N3994A		–	1.2	
(V_{DS} = –10 Vdc, V_{GS} = 10 Vdc, T_A = 150°)	2N3993, 2N3993A		–	1.0	μAdc
(V_{DS} = –10 Vdc, V_{GS} = 6.0 Vdc, T_A = 150°)	2N3994, 2N3994A		–	1.0	
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (Note 1)		I_{DSS}			mAdc
(V_{DS} = –10 Vdc, V_{GS} = 0)	2N3993		10		
	2N3994, 2N3994A		2.0	–	
Gate-Source Voltage		V_{GS}			Vdc
(V_{DS} = –10 Vdc, I_D = –1.0 μAdc)	2N3993		4.0	9.5	
	2N3994, 2N3994A		1.0	5.5	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance		$r_{ds(on)}$			Ohms
(V_{GS} = 0, I_D = 0,f = 1.0 kHz)	2N3993		–	150	
	2N3994, 2N3994A		–	300	
Forward Transadmittance (Note 1)		$\lvert y_{fs} \rvert$			mmhos
(V_{DS} = –10 Vdc, V_{GS} = 0,f = 1.0 kHz)	2N3993		6.0	12	
	2N3994		4.0	10	
	2N3994A		5.0	10	
Input Capacitance		C_{iss}			pF
(V_{DS} = –10 Vdc, V_{GS} = 0,f = 1.0 MHz)	2N3993, 2N3994		–	16	
	2N3994A		–	12	
Reverse Transfer Capacitance		C_{rss}			pF
(V_{DS} = 0, V_{GS} = 10 Vdc, f = 1.0 MHz)	2N3993		–	4.5	
(V_{DS} = 0, V_{GS} = 6.0 Vdc, f = 1.0 MHz)	2N3994		–	5.0	
	2N3994A		–	3.5	

*Indicates JEDEC Registered Data.
Note 1: Pulse Test: Pulse With = 100 ms, Duty Cycle ≤ 10%

2N4012 (SILICON)



stud isolated from case

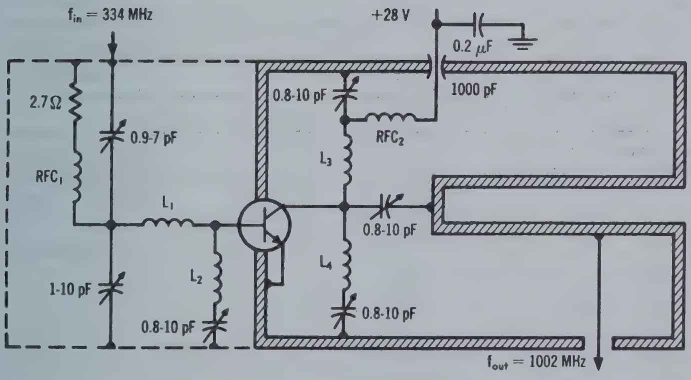
CASE 36
(TO-60)

NPN silicon annular transistor, designed for frequency-multiplication applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage ($V_{EB(off)}$ = 1.5 Vdc)	V_{CEV}	65	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	1.5	Amps
Total Device Dissipation @ T_A = 25°C Derate Above 25°C	P_D	11.6 66.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J,T_{stg}	-65 to +200	°C

FIGURE 1 — TRIPLER TEST CIRCUIT


f_{in} = 334 MHz
+28 V
0.2 μF
1000 pF
2.7 Ω
0.9-7 pF
RFC₁
0.8-10 pF
RFC₂
L₃
L₁
0.8-10 pF
L₄
L₂
1-10 pF
0.8-10 pF
0.8-10 pF
f_{out} = 1002 MHz

RFC_1 = 0.22 μH
RFC_2 = 0.33 OHMS, W.W. RESISTOR
L_1 = 2 TURNS, ⅜″ DIAMETER, NO. 16 WIRE
L_2 = 1/16″ WIDTH COPPER STRIP, ⅜″ LONG
L_3 = 2 TURNS, ⅜″ DIAMETER, NO. 18 WIRE
L_4 = 1½ TURNS, ⅜″ DIAMETER, 1/16″ COPPER STRIP
OUTPUT CAVITY = 1¼″ X 1¼″ X 2¼″
CENTER CONDUCTOR = ¼″ OD TUBE
OUTPUT DIRECT COUPLE = 1″ FROM SHORTED END

2N4012 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage[1] (I_C = 0 to 200 mAdc, I_B = 0)	BV_{CEO}	40	-	-	Vdc
Collector-Emitter Breakdown Voltage[1] (I_C = 0 to 200 mAdc, $V_{EB(off)}$ = 1.5 Vdc)	BV_{CEV}	65	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	65	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4	-	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	-	0.1	mAdc
ON CHARACTERISTICS					
DC Current-Gain (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc) (I_C = 125 mAdc, V_{CE} = 5.0 Vdc)	h_{FE1} h_{FE2}	4.0 10	– –	40 –	– –
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 100 mAdc)	$V_{CE(sat)}$	-	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 125 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	f_T	-	350	-	MHz
Collector-Base Cutoff Frequency † (V_{CE} = 28 Vdc, I_C = 0)	f_c	-	25	-	GHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0)	C_{ob}	-	-	10	pF
Base-Spreading Resistance (I_C = 250 mAdc, V_{CE} = 28 Vdc, f = 400 MHz)	$r_{bb'}$	-	10	-	Ohms

FUNCTIONAL TEST

		Symbol	Min	Typ	Max	Unit
Power Output	Tripler (Test Circuit Figure 1) V_{CE} = 28 Vdc, P_{in} = 1 W, f_{in} = 334 MHz, f_{out} = 1002 MHz	P_{out}	2.5	-	-	Watts
Efficiency		η	25	-	-	%
Power Output	Doubler V_{CE} = 28 Vdc, P_{in} = 1 W, f_{in} = 400 MHz, f_{out} = 800 MHz	P_{out}	-	3.0	-	Watts
Efficiency		η	-	35	-	%

(1) Pulsed through a 25 mH inductor; duty cycle = 50%

† f_c is determined from Q measured at 210 MHz. f_c = Q x 210 MHz.

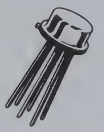
2N4015 (SILICON)
2N4016

DUAL PNP SILICON ANNULAR TRANSISTORS

. . . designed for differential amplifier applications.

- Collector-Emitter Breakdown Voltage —
  BV_{CEO} = 60 Vdc (Min) @ I_C = 10 mAdc
- Collector-Base Breakdown Voltage —
  BV_{CBO} = 60 Vdc (Min) @ I_C = 0.01 mAdc
- Low Noise Figure —
  NF = 4.0 dB (Max) @ I_C = 0.03 mAdc
- Low Base-Voltage Differential —
  $V_{BE1}-V_{BE2}$ = 2.5 mVdc (Max) 2N4016
- Tight DC Current Gain Ratio —
  h_{FE1}/h_{FE2} = 0.9 to 1.0

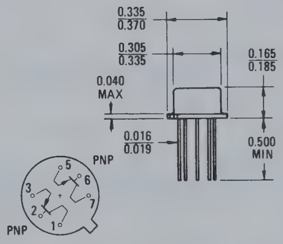
PNP SILICON
MATCHED DUAL
TRANSISTORS



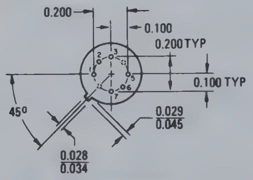
*MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	300		mAdc
Base Current	I_B	100		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		Each Transistor	Total Package	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.29	500 2.86	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.85 4.85	1.4 8.0	Watts mW/°C

*Indicates JEDEC Registered Data.


0.335
0.370
0.305
0.335
0.165
0.185
0.040
MAX
0.016
0.019
0.500
MIN
PNP
5
6
3
7
2
1
PNP

Pin Connections, Bottom View


0.200
0.100
0.200 TYP
0.100 TYP
1
2
3
5
6
7
45°
0.029
0.045
0.028
0.034

PINS 4 AND 8 OMITTED
All Leads Electrically Isolated from Case

CASE 654-04
Formerly Case 32-02

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	60	–	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	60	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current	I_{CBO}			
(V_{CB} = 50 Vdc, I_E = 0)		–	10	nAdc
(V_{CB} = 50 Vdc, I_E = 0, T_A = +150°C)		–	10	µAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)	I_{EBO}	–	0.1	µAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			–
(I_C = 0.01 mAdc, V_{CE} = 5.0 Vdc)		80	–	
(I_C = 0.1 mAdc, V_{CE} = 5.0 Vdc)		120	–	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		135	350	
(I_C = 50 mAdc, V_{CE} = 5.0 Vdc)(1)		115	–	
Collector-Emitter Saturation Voltage(1) (I_C = 50 mAdc, I_B = 2.5 mAdc)	$V_{CE(sat)}$	–	0.25	Vdc
Base-Emitter Saturation Voltage(1) (I_C = 50 mAdc, I_B = 2.5 mAdc)	$V_{BE(sat)}$	–	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product(2)	f_T			MHz
(I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		200	600	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)		60	–	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	–	8.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	–	25	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	–	11.5	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	–	15	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	135	420	–
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	–	80	µmhos
Noise Figure (I_C = 0.03 mAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz, BW = 200 Hz)	NF	–	4.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio (I_C = 0.1 to 1.0 mAdc, V_{CE} = 5.0 Vdc)	h_{FE1}/h_{FE2}	0.9	1.0	–
Base Voltage Differential (I_C = 0.1 to 1.0 mAdc, V_{CE} = 5.0 Vdc 2N4015	$\lvert V_{BE1}-V_{BE2}\rvert$	–	5.0	mVdc
2N4016		–	2.5	
Base Voltage Differential Gradient	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$			mVdc
(I_C = 0.1 to 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = –55°C to +25°C) 2N4015		–	1.6	
2N4016		–	0.8	
(I_C = 0.1 to 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = +25°C to +125°C) 2N4015		–	2.0	
2N4016		–	1.0	

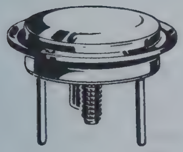
*Indicates JEDEC Registered Data.

(1)Pulse Test: Pulse Width = 300 µs, Duty Cycle = 1.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N4048 thru 2N4053 (GERMANIUM)

CASE 7



Collector connected to case

PNP germanium power transistors designed for high-current applications requiring high gain and extremely low saturation voltage.

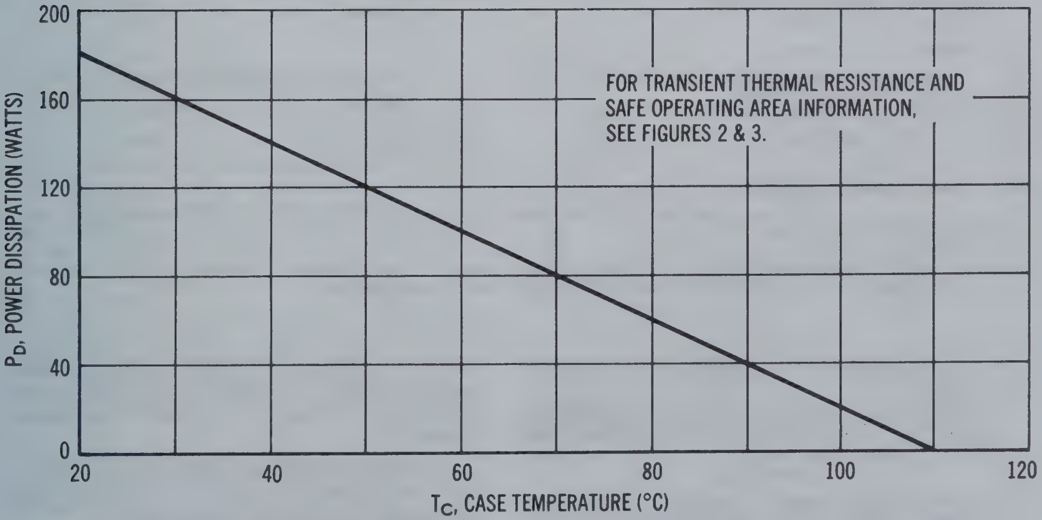
MAXIMUM RATINGS

Rating	Symbol	2N4048 2N4051	2N4049 2N4052	2N4050 2N4053	Unit
Collector-Emitter Voltage	V_{CEO}	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	30	40	Vdc
Collector Current — Continuous	I_C*	← 60 →			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	← 170 → ← 2.0 →			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	← 0.5 →	°C/W

FIGURE 1 — AVERAGE POWER-TEMPERATURE DERATING CURVE



* JEDEC Registered Values, For True Capability See Figure 3

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage†		BV_{CEO}†			Vdc
($I_C = 1.0$ Adc, $I_B = 0$)	2N4048, 2N4051		30	-	
	2N4049, 2N4052		45	-	
	2N4050, 2N4053		60	-	
Collector-Emitter Breakdown Voltage		BV_{CES}			Vdc
($I_C = 300$ mAdc, $V_{BE} = 0$)	2N4048, 2N4051		45	-	
	2N4049, 2N4052		60	-	
	2N4050, 2N4053		75	-	
Floating Potential		V_{EBF}			Vdc
($V_{CB} = 45$ Vdc, $I_E = 0$)	2N4048, 2N4051		-	0.5	
($V_{CB} = 60$ Vdc, $I_E = 0$)	2N4049, 2N4052		-	0.5	
($V_{CB} = 75$ Vdc, $I_E = 0$)	2N4050, 2N4053		-	0.5	
Collector Cutoff Current		I_{CEX}			mAdc
($V_{CE} = 30$ Vdc, $V_{BE(off)} = 2.0$ Vdc, $T_C = +71°C$)	2N4048, 2N4051		-	15	
($V_{CE} = 45$ Vdc, $V_{BE(off)} = 2.0$ Vdc, $T_C = +71°C$)	2N4049, 2N4052		-	15	
($V_{CE} = 60$ Vdc, $V_{BE(off)} = 2.0$ Vdc, $T_C = +71°C$)	2N4050, 2N4053		-	15	
Collector Cutoff Current		I_{CBO}			mAdc
($V_{CB} = 2.0$ Vdc, $I_E = 0$)			-	0.2	
($V_{CB} = 45$ Vdc, $I_E = 0$)	2N4048, 2N4051		-	4.0	
($V_{CB} = 60$ Vdc, $I_E = 0$)	2N4049, 2N4052		-	4.0	
($V_{CB} = 75$ Vdc, $I_E = 0$)	2N4050, 2N4053		-	4.0	
Emitter Cutoff Current		I_{EBO}			mAdc
($V_{BE} = 25$ Vdc, $I_C = 0$)	2N4048, 2N4051		-	4.0	
($V_{BE} = 25$ Vdc, $I_C = 0$, $T_C = +71°C$)			-	15	
($V_{BE} = 30$ Vdc, $I_C = 0$)	2N4049, 2N4052		-	4.0	
($V_{BE} = 30$ Vdc, $I_C = 0$, $T_C = +71°C$)			-	15	
($V_{BE} = 40$ Vdc, $I_C = 0$)	2N4050, 2N4053		-	4.0	
($V_{BE} = 40$ Vdc, $I_C = 0$, $T_C = +71°C$)			-	15	
ON CHARACTERISTICS					
DC Current Gain†		h_{FE}†			-
($I_C = 15$ Adc, $V_{CE} = 2.0$ Vdc)	2N4048, 2N4049, 2N4050		60	180	
	2N4051, 2N4052, 2N4053		120	240	
($I_C = 60$ Adc, $V_{CE} = 2.0$ Vdc)			15	-	
Collector-Emitter Saturation Voltage†		$V_{CE(sat)}$†			Vdc
($I_C = 15$ Adc, $I_B = 1.0$ Adc)			-	0.15	
($I_C = 60$ Adc, $I_B = 6.0$ Adc)			-	0.3	
Base-Emitter Saturation Voltage†		$V_{BE(sat)}$†			Vdc
($I_C = 15$ Adc, $I_B = 1.0$ Adc)			-	0.6	
($I_C = 60$ Adc, $I_B = 6.0$ Adc)			-	1.0	
SMALL SIGNAL CHARACTERISTICS					
Common-Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
($I_C = 15$ Adc, $V_{CE} = 2.0$ Vdc)			2.0	-	

† To avoid excessive heating of the collector junction, perform test with pulse method.

The switching performance of this transistor is determined primarily by the gain-bandwidth product, f_T*, and the behavior of the base-spreading resistance, r_B'.

In the case of rise time, the base-spreading resistance plays a small part, and the test circuit delivers a constant current step of turn-on current to the transistor (I_{B1}). Therefore, the curve of t_r on Figure 6 follows theory closely, i.e.:

$$t_r = 0.8 \frac{I_C}{I_{B1}} \cdot \frac{1}{2\pi f_T}$$

From the curve, it can be seen that f_T is roughly constant with current; using the equation, its large signal value can be calculated to be approximately 120 kHz at the 20-Amp level. A lower supply voltage will increase rise time slightly.

Turn-off time is slow because of conductivity modulation which occurs in the base region. When the transistor is held "on" in saturation, the base region becomes filled with excess charge; i.e., charge in excess of that necessary to sustain the circuit limited value of I_C. As a result, the base resistivity and consequently r_B' become very low. During turn off, as the excess charge is reduced, the accompanying increase in resistivity causes a marked reduction in the turn-off current, i_{B2}, as can be seen from the waveforms of Figure 5. During fall time, the i_{B2} current is very low causing an extended fall time.

Only a slight improvement in turn-off performance is achieved with a "speed-up" capacitor placed across R_B. This unusual behavior occurs because r_B' limits the amount of reverse current which can be achieved. Also, it seems evident that r_B' increases with applied reverse current, so that efforts to speed up the turn-off behavior are somewhat futile.

In most applications, switching time will be close to the values shown on Figure 6. Delay time is not shown as it is negligible in comparison to the other times.

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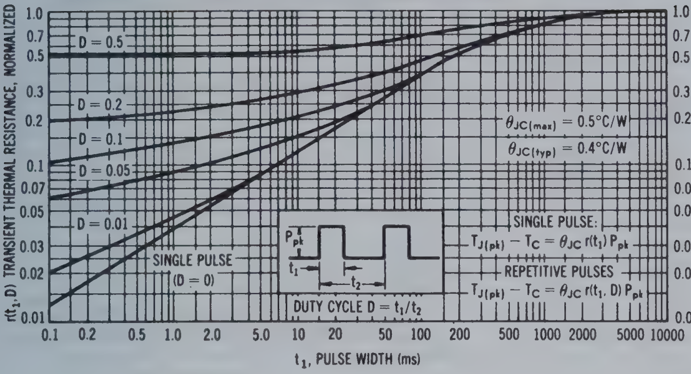
* $f_T \approx f_{\alpha e} \times h_{fe}$

2N4048 thru 2N4053 (continued)

FIGURE 2 — TRANSIENT THERMAL RESISTANCE



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation; i.e. the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 3 is based on $T_{J(pk)} = 110°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 110°C$. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 3 — ACTIVE REGION SAFE-OPERATING AREA

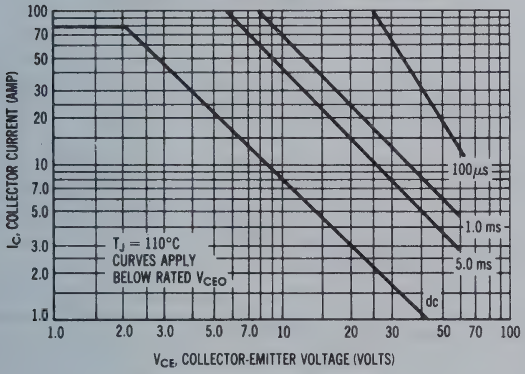
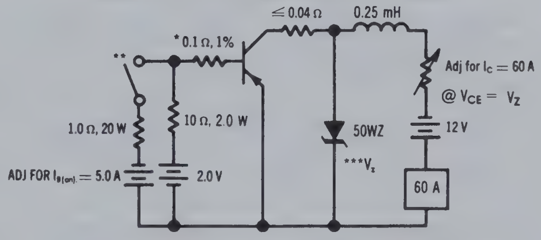


FIGURE 4 — SAFE OPERATING AREA TEST CIRCUIT


≤ 0.04 Ω
0.25 mH
*0.1 Ω, 1%
**
Adj for IC = 60 A
@ VCE = VZ
1.0 Ω, 20 W
10 Ω, 2.0 W
50WZ
12 V
***VZ
ADJ FOR IB(on) = 5.0 A
2.0 V
60 A

*NOT REQUIRED IF CURRENT PROBE USED TO READ $I_{B(on)}$

**PRF ≈ 60 Hz

SERIES IMPEDANCE & INDUCTANCE MUST BE KEPT TO A MINIMUM.

***ZENER SELECTED TO ESTABLISH SAFE OPERATING AREA VOLTAGE.

@ I_C = 60 Adc:
2N4048, 2N4051 = 35 Vdc
2N4049, 2N4052 = 40 Vdc
2N4050, 2N4053 = 45 Vdc

FIGURE 5 — SWITCHING TEST CIRCUIT

TO OBTAIN DATA FOR FIGURE 6, R_B & R_L WERE VARIED. V_{CC} and V_1 LEVELS REMAINED APPROXIMATELY AS SHOWN.

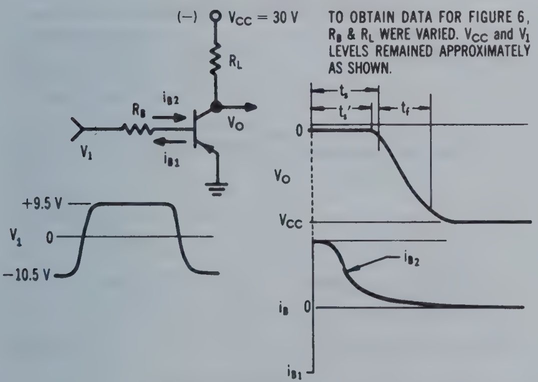
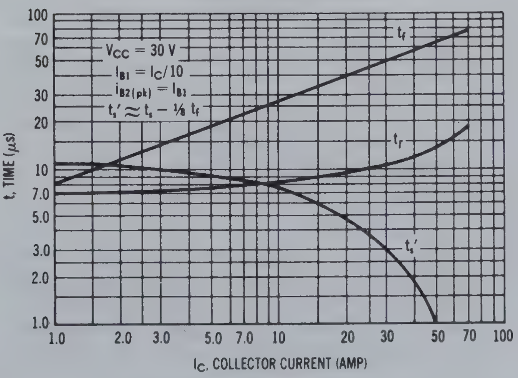

(−) VCC = 30 V
RL
RB
iB2
iB1
VO
V₁
+9.5 V
V₁ 0
−10.5 V
ts
ts′
tf
0
VO
VCC
iB2
iB 0
iB1

FIGURE 6 — SWITCHING TIMES



TYPICAL DC CHARACTERISTICS

FIGURE 7 — DC CURRENT GAIN

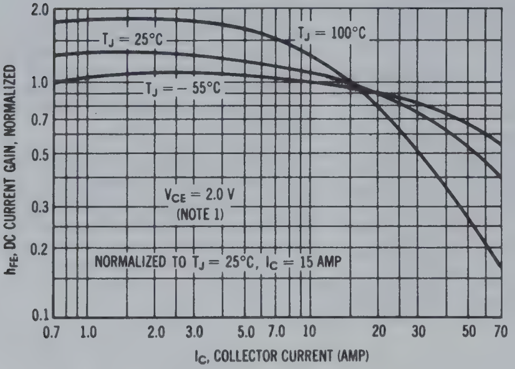


FIGURE 8 — COLLECTOR SATURATION REGION

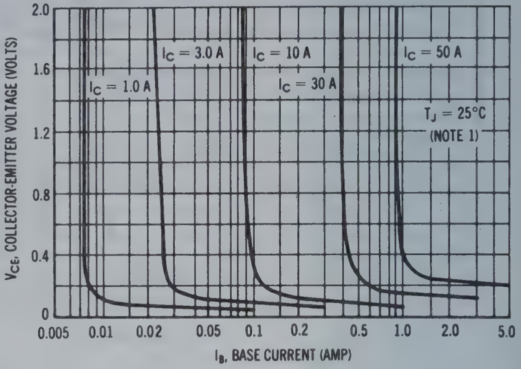


FIGURE 9 — EFFECTS OF BASE-EMITTER RESISTANCE

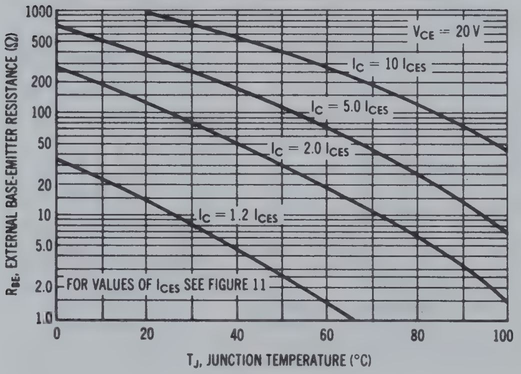


FIGURE 10 — "ON" VOLTAGES

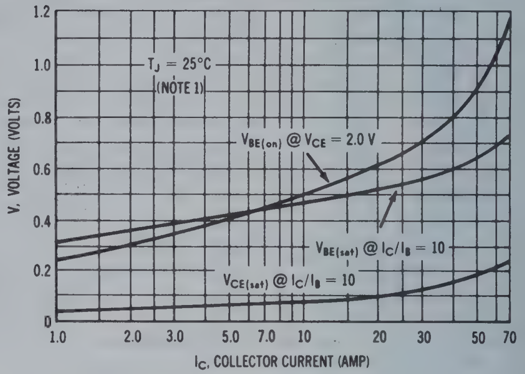
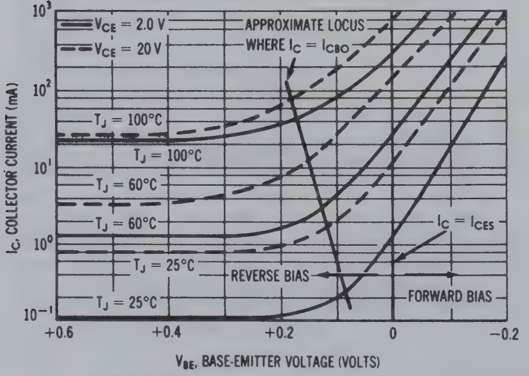
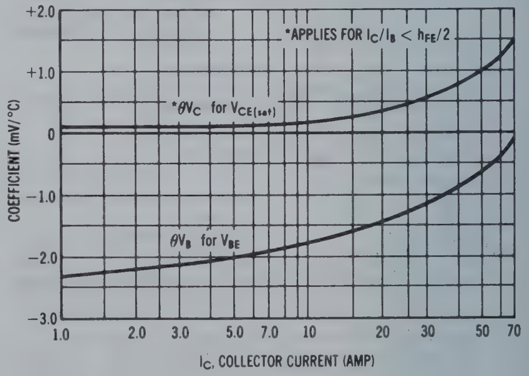


FIGURE 11 — COLLECTOR CUTOFF REGION



NOTE 1: Data is obtained from pulse tests and adjusted to nullify the effect of I_{CBO}.

FIGURE 12 — TEMPERATURE COEFFICIENTS



2N4066 (SILICON)
2N4067

DUAL P-CHANNEL MOS FIELD-EFFECT TRANSISTORS

Enhancement Mode MOS Field-Effect Transistors designed primarily for low-power, chopper or switching applications.

- High Forward Transadmittance –
  $|y_{fs}|$ = 2.5 mmhos (Min) @ V_{DS} = −15 Vdc (2N4067)

- Low Forward Gate Current –
  I_{GF} = 2.5 pAdc (Max) @ V_{GS} = −25 Vdc

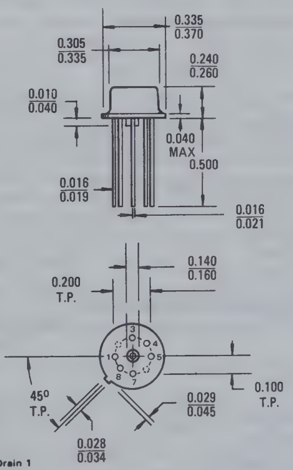
- Low Drain-Source "ON" Resistance –
  $r_{ds(on)}$ = 250 Ohms (Max) @ V_{GS} = −15 Vdc (2N4067)

DUAL P-CHANNEL MOS FIELD-EFFECT TRANSISTORS

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-30	Vdc
Drain-Gate Voltage	V_{DG}	-25	Vdc
Reverse Gate-Source Voltage	V_{GSR}	+25	Vdc
Forward Gate-Source Voltage	V_{GSF}	-25	Vdc
Drain Current	I_D	200	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	0.6 4.0	Watt mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	1.7 11.3	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Operating Junction Temperature Range	T_J	-65 to +175	°C

*Indicates JEDEC Registered Data.


0.335
0.370
0.305
0.335
0.240
0.260
0.010
0.040
0.040
MAX
0.500
0.016
0.019
0.016
0.021
0.140
0.160
0.200
T.P.
3
4
5
1
8
7
45°
T.P.
0.029
0.045
0.100
T.P.
0.028
0.034

Pin 1. Drain 1
3. Gate 1
4. Substrate.
5. Gate 2
7. Drain 2
8. Source 1 and 2

Case 642-01

2N4066, 2N4067 (continued)

*ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage (I_D = 10 μAdc, V_{GS} = 0)	$V_{(BR)DSS}$	-30	–	Vdc
Source-Drain Breakdown Voltage (I_S = 10 μAdc, V_{GD} = 0)	$V_{(BR)SDS}$	-30	–	Vdc
Zero-Gate Voltage Source Current	I_{SDS}			
(V_{SD} = -15 Vdc, V_{GD} = 0)		–	1.0	nAdc
(V_{SD} = -15 Vdc, V_{GD} = 0, T_A = 150°C)		–	2.0	μAdc
Zero-Gate Voltage Drain Current (Note 1)	I_{DSS}			
(V_{DS} = -15 Vdc, V_{GS} = 0)		–	1.0	nAdc
(V_{DS} = -15 Vdc, V_{GS} = 0, T_A = 150°C)		–	2.0	μAdc
ON CHARACTERISTICS				
Gate-Source Threshold Voltage (V_{DS} = -15 Vdc, I_D = 10 μAdc)	$V_{GS(TH)}$	-3.0	-6.0	Vdc
Forward Gate Current (V_{GS} = -25 Vdc, V_{DS} = 0)	I_{GF}	–	2.5	pAdc
"ON" Drain Current (V_{DS} = -15 Vdc, V_{GS} = -15 Vdc)	$I_{D(on)}$	10	50	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Static Drain-Source "ON" Resistance	$r_{ds(on)}$			Ohms
(V_{GS} = -15 Vdc, I_D = 0, f = 1.0 kHz) 2N4066		–	500	
2N4067		–	250	
Forward Transadmittance (Note 1)	$\lvert y_{fs} \rvert$			mmhos
(V_{DS} = -15 Vdc, V_{GS} = -15 Vdc, f = 1.0 kHz) 2N4066		1.5	–	
2N4067		2.5	–	
(V_{DS} = -15 Vdc, V_{GS} = -15 Vdc, f = 1.0 kHz, T_A = 100°C) 2N4066		1.0	–	
2N4067		1.75	–	
Output Admittance (V_{DS} = -15 Vdc, V_{GS} = -15 Vdc, f = 1.0 kHz)	$\lvert y_{os} \rvert$	–	300	μmhos
Input Capacitance (V_{DS} = -15 Vdc, V_{GS} = -15 Vdc, f = 1.0 MHz)	C_{iss}	–	7.0	pF
Reverse Transfer-Capacitance (V_{DS} = 0, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	–	1.5	pF
Source-Substrate Capacitance (V_{DU} = -15 Vdc, V_{GS} = 0, I_S = 0, f = 1.0 MHz)	C_{SU}	–	5.0	pF
Drain-Substrate Capacitance (V_{SU} = -15 Vdc, V_{GS} = 0, I_S = 0, f = 1.0 MHz)	C_{DU}	–	5.0	pF

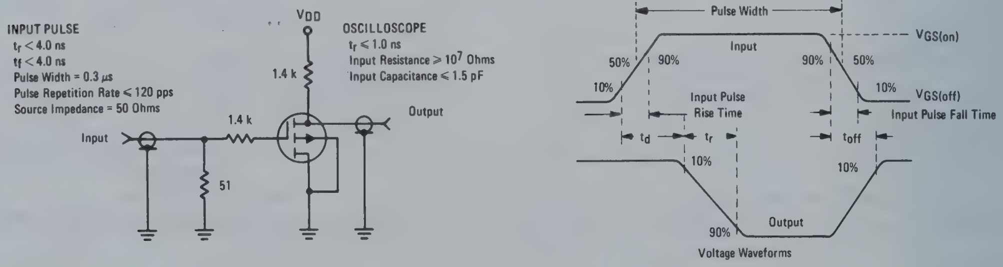
SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Delay Time	(V_{DD} = -15 Vdc, $I_{D(on)}$ = 10 mAdc, $V_{GS(on)}$ = -15 Vdc, $V_{GS(off)}$ = 0)	t_d	–	20	ns
Rise Time		t_r	–	30	ns
Turn-Off Time		t_{off}	–	50	ns

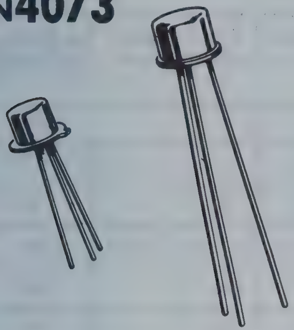
*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width ≤ 630 ms, Duty Cycle ≤ 10%.

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT


INPUT PULSE
t_r < 4.0 ns
t_f < 4.0 ns
Pulse Width = 0.3 μs
Pulse Repetition Rate ≤ 120 pps
Source Impedance = 50 Ohms
Input
V_{DD}
1.4 k
1.4 k
51
OSCILLOSCOPE
t_r ≤ 1.0 ns
Input Resistance ≥ 10^7 Ohms
Input Capacitance ≤ 1.5 pF
Output
Pulse Width
$V_{GS(on)}$
Input
50%
90%
90%
50%
10%
10%
$V_{GS(off)}$
Input Pulse Rise Time
Input Pulse Fall Time
t_d
t_r
t_{off}
10%
10%
90%
Output
Voltage Waveforms

2N4072 (SILICON)
2N4073



CASE 22
(TO-18)
2N4072

CASE 31
(TO-5)
2N4073

Collector connected to case

NPN silicon annular transistors designed as amplifiers and drivers for large-signal VHF and UHF applications.

MAXIMUM RATINGS

Rating	Symbol	2N4072	2N4073	Unit
Collector-Emitter Voltage	V_{CEO}	20		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current-Continuous	I_C	100	150	mAdc
Total Device Dissipation @ T_A = 25°C Derate Above 25°C	P_D	0.35 2.0	- -	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	- -	1.5 8.57	Watts mW/°C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
STATIC CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 15 mAdc, I_B = 0)	$BV_{CEO(sus)}$	20	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	- -	0.1 100	µAdc
DC Current Gain (I_C = 25 mAdc, V_{CE} = 2 Vdc)	h_{FE}	10	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 25 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	-	550	-	MHz
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	3.0	4.0	pF

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
FUNCTIONAL TEST						
Power Gain	2N4072 Test Circuit - Figure 5 P_{in} = 25 mW, V_{CE} = 13.6 Vdc, f = 175 MHz	G_{PE}	10	-	-	dB
Power Output		P_{out}	250	-	-	mW
Collector Effecincy		η	50	60	-	%
Power Gain	2N4073 Test Circuit - Figure 5 P_{in} = 50 mW, V_{CE} = 13.6 Vdc, f = 175 MHz	G_{PE}	10	-	-	dB
Power Output		P_{out}	500	650	-	mW
Collector Efficiency		η	50	65	-	%

2N4072

FIGURE 1 — POWER OUTPUT versus FREQUENCY

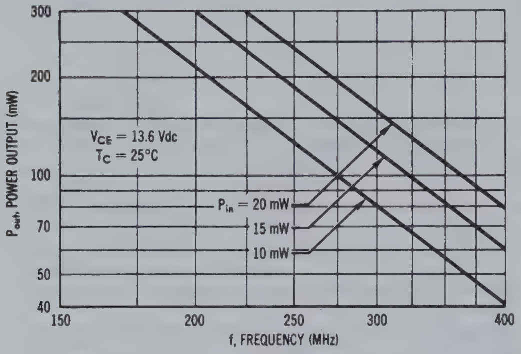
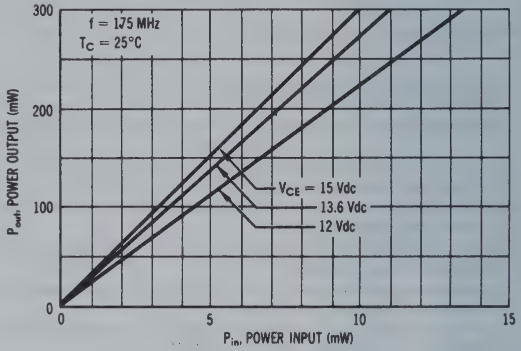


FIGURE 2 — POWER OUTPUT versus POWER INPUT



2N4073

FIGURE 3 — POWER OUTPUT versus FREQUENCY

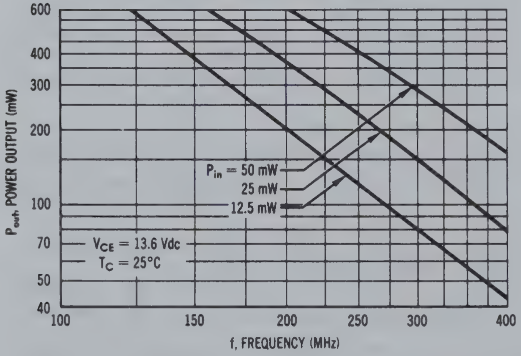


FIGURE 4 — POWER OUTPUT versus POWER INPUT

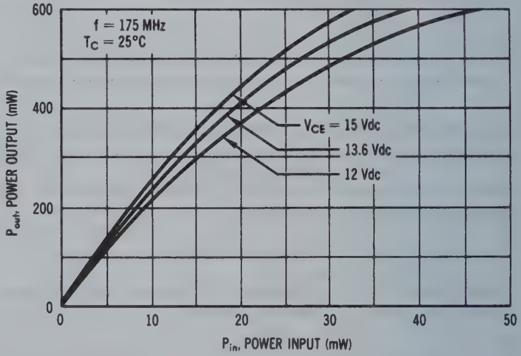
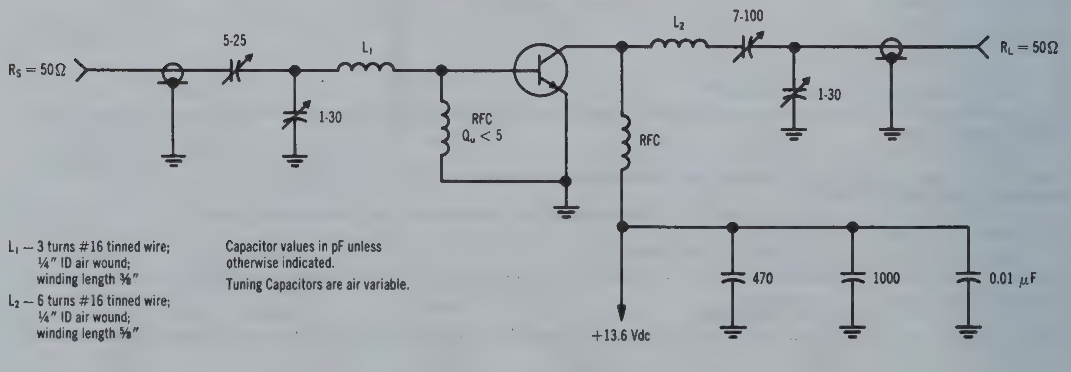


FIGURE 5 — 175 MHz TEST CIRCUIT



L_1 — 3 turns #16 tinned wire; ¼″ ID air wound; winding length ⅜″

L_2 — 6 turns #16 tinned wire; ¼″ ID air wound; winding length ⅝″

Capacitor values in pF unless otherwise indicated.

Tuning Capacitors are air variable.

2N4091 (SILICON)
2N4092
2N4093

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

Depletion Mode (Type A) Junction Field-Effect Transistors designed for chopper and high-speed switching applications.

- Low Drain-Source "On" Resistance — $r_{ds(on)}$ = 30 Ohms (Max) @ f = 1.0 kHz (2N4091)
- Low Source Reverse Current — I_{SGO} = 0.2 nAdc (Max) @ V_{SG} = 20 Vdc
- Guaranteed Switching Characteristics

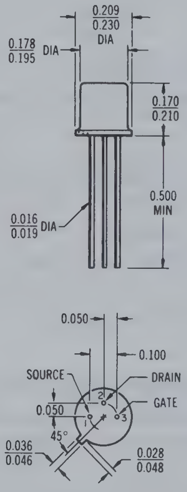
N-CHANNEL

JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)

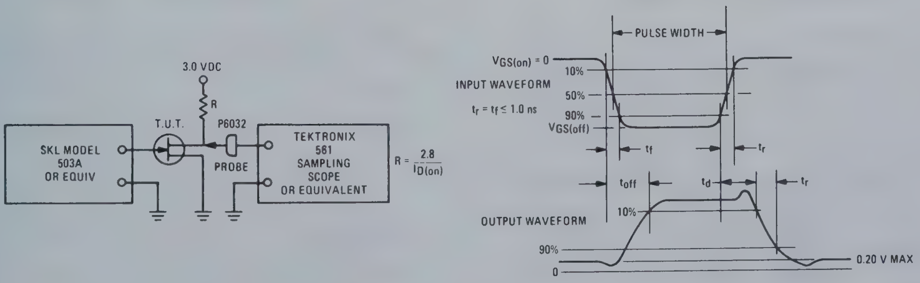
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Gate-Source Voltage	V_{GS}	40	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
SOURCE
DRAIN
GATE
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

CASE 22 (3)
(TO-18)

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT


3.0 VDC
R
T.U.T.
P6032
SKL MODEL
503A
OR EQUIV
PROBE
TEKTRONIX
561
SAMPLING
SCOPE
OR EQUIVALENT
R = 2.8 / I_D(on)
PULSE WIDTH
VGS(on) = 0
10%
INPUT WAVEFORM
50%
tr = tf ≤ 1.0 ns
90%
VGS(off)
tf
tr
toff
td
tr
10%
OUTPUT WAVEFORM
90%
0
0.20 V MAX

2N4091, 2N4092, 2N4093 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	40	-	Vdc
Drain-Gate Breakdown Voltage (I_D = 1.0 μAdc, I_S = 0)		$V_{(BR)DGO}$	40	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 20 Vdc, I_D = 1.0 nAdc)	2N4091	$V_{GS(off)}$	5.0	10	Vdc
	2N4092		2.0	7.0	
	2N4093		1.0	5.0	
Source Reverse Current (V_{SG} = 20 Vdc, I_D = 0)		I_{SGO}	-	0.2	nAdc
Drain Reverse Current (V_{DG} = 20 Vdc, I_S = 0)		I_{DGO}	-	0.2	nAdc
(V_{DG} = 20 Vdc, I_D = 0, T_A = 150°C)			-	0.4	μAdc
Drain-Cutoff Current (V_{DS} = 20 Vdc, V_{GS} = 12 Vdc)	2N4091	$I_{D(off)}$	-	0.2	nAdc
(V_{DS} = 20 Vdc, V_{GS} = 8.0 Vdc)	2N4092		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 6.0 Vdc)	2N4093		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 12 Vdc, T_A = 150°C)	2N4091		-	0.4	μAdc
(V_{DS} = 20 Vdc, V_{GS} = 8.0 Vdc, T_A = 150°C)	2N4092		-	0.4	
(V_{DS} = 20 Vdc, V_{GS} = 6.0 Vdc, T_A = 150°C)	2N4093		-	0.4	
ON CHARACTERISTICS					
Zero-Gate Voltate Drain Current [1] (V_{DS} = 20 Vdc, V_{GS} = 0)	2N4091	I_{DSS}	30	-	mAdc
	2N4092		15	-	
	2N4093		8.0	-	
Drain-Source "ON" Voltage (I_D = 6.6 mAdc, V_{GS} = 0)	2N4091	$V_{DS(on)}$	-	0.2	Vdc
(I_D = 4.0 mAdc, V_{GS} = 0)	2N4092		-	0.2	
(I_D = 2.5 mAdc, V_{GS} = 0)	2N4093		-	0.2	
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0)	2N4091	$r_{DS(on)}$	-	30	Ohms
	2N4092		-	50	
	2N4093		-	80	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N4091	$r_{ds(on)}$	-	30	Ohms
	2N4092		-	50	
	2N4093		-	80	
Input Capacitance (V_{DS} = 20 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	16	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 20 Vdc, f = 1.0 MHz)		C_{rss}	-	5.0	pF
SWITCHING CHARACTERISTICS					
Delay Time (See Figure 1) ($I_{D(on)}$ = 6.6 mAdc)	2N4091	t_d	-	15	ns
($I_{D(on)}$ = 4.0 mAdc)	2N4092		-	15	
($I_{D(on)}$ = 2.5 mAdc)	2N4093		-	20	
Rise Time (See Figure 1) ($I_{D(on)}$ = 6.6 mAdc)	2N4091	t_r	-	10	ns
($I_{D(on)}$ = 4.0 mAdc)	2N4092		-	20	
($I_{D(on)}$ = 2.5 mAdc)	2N4093		-	40	
Turn-Off Time (See Figure 1) ($V_{GS(off)}$ = 12 Vdc)	2N4091	t_{off}	-	40	ns
($V_{GS(off)}$ = 8.0 Vdc)	2N4092		-	60	
($V_{GS(off)}$ = 6.0 Vdc)	2N4093		-	80	

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%.

2N4123 (SILICON)
2N4124

CASE 29(1)
(TO-92)

NPN silicon transistors designed for general purpose switching and amplifier applications and for complementary circuitry with PNP types 2N4125 and 2N4126. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS

Rating	Symbol	2N4123	2N4124	Unit
Collector-Emitter Voltage	V_{CEO}	30	25	Vdc
Collector-Base Voltage	V_{CB}	40	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	350 2.73		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — CAPACITANCE

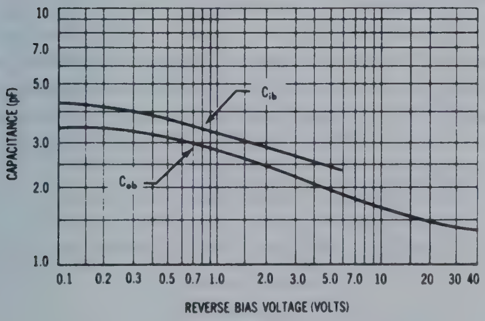
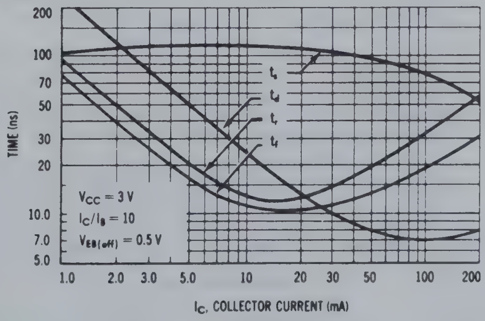


FIGURE 2 — SWITCHING TIMES



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (1) (I_C = 1 mAdc, I_E = 0)	2N4123		BV_{CEO}	30	–	Vdc
	2N4124			25	–	
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N4123		BV_{CBO}	40	–	Vdc
	2N4124			30	–	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)			I_{CBO}	–	50	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)			I_{EBO}	–	50	nAdc
ON CHARACTERISTICS						
DC Current Gain (1) (I_C = 2 mAdc, V_{CE} = 1 Vdc)	2N4123	9	h_{FE}	50	150	–
	2N4124			120	360	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N4123			25	–	
	2N4124			60	–	
Collector-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5 mAdc)		10, 11	$V_{CE(sat)}$	–	0.3	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 50 mAdc, I_B = 5 mAdc)		11	$V_{BE(sat)}$	–	0.95	Vdc
SMALL SIGNAL CHARACTERISTICS						
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4123		$\lvert h_{fe} \rvert$	2.5	–	–
	2N4124			3.0	–	
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4123		f_T	250	–	MHz
	2N4124			300	–	
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)		1	C_{ob}	–	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		1	C_{ib}	–	8.0	pF
Small-Signal Current Gain (I_C = 2 mAdc, V_{CE} = 1 Vdc, f = 1 kHz)	2N4123	5	h_{fe}	50	200	–
	2N4124			120	480	
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1 k ohm, Noise Bandwidth = 10 Hz to 15.7 kHz)	2N4123	3, 4	NF	–	6.0	dB
	2N4124			–	5.0	

SWITCHING CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Typ	Unit
Delay Time	V_{CC} = 3 Vdc, $V_{EB(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1 mAdc	2	t_d	24	ns
Rise Time		2	t_r	13	ns
Storage Time	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1 mAdc	2	t_s	125	ns
Fall Time		2	t_f	11	ns

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 5 Vdc, T_A = 25°C

FIGURE 3 — FREQUENCY VARIATIONS

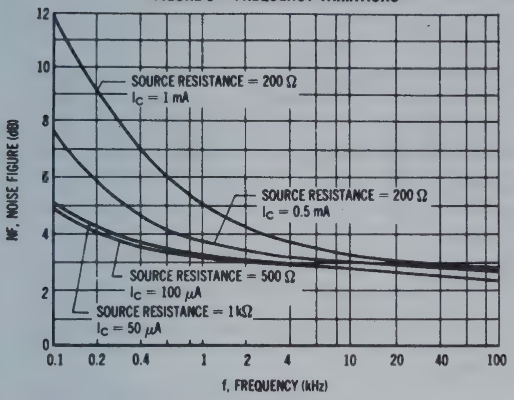
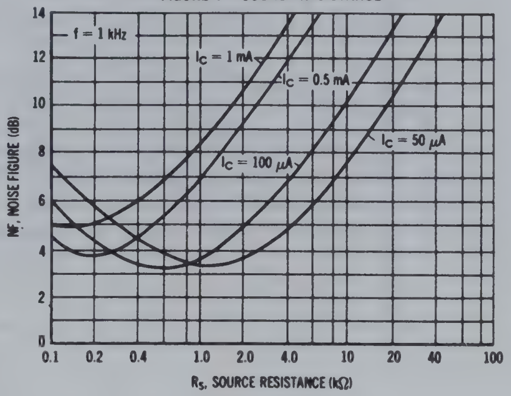


FIGURE 4 — SOURCE RESISTANCE



h PARAMETERS

V_{CE} = 10 V, f = 1 kHz, T_A = 25°C

FIGURE 5 — CURRENT GAIN

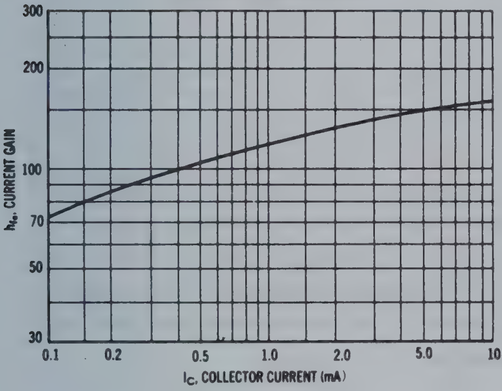


FIGURE 6 — OUTPUT ADMITTANCE

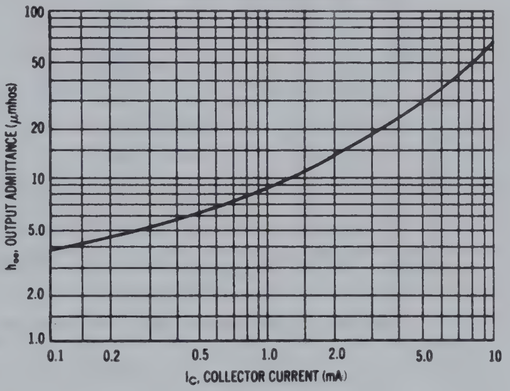


FIGURE 7 — INPUT IMPEDANCE

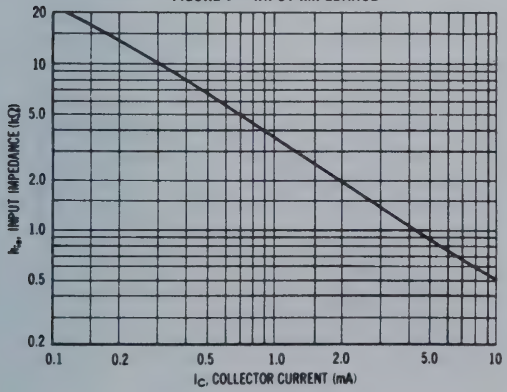
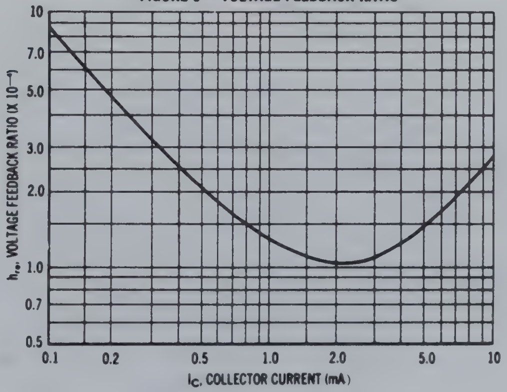


FIGURE 8 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 9 — NORMALIZED CURRENT GAIN

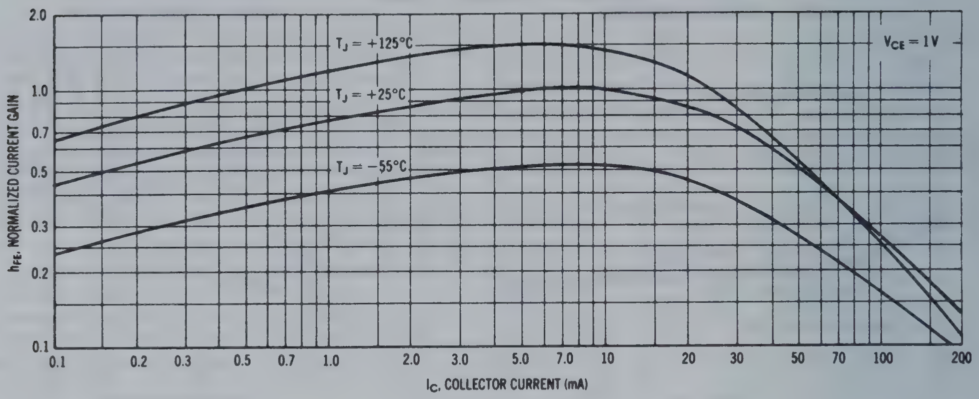


FIGURE 10 — COLLECTOR SATURATION REGION

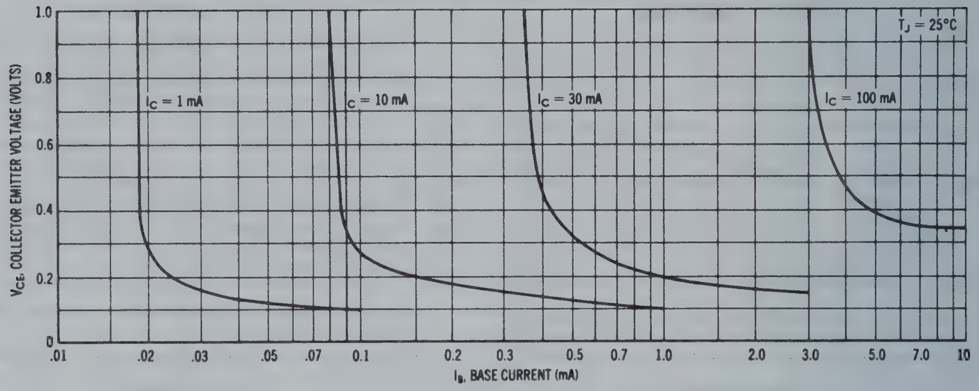


FIGURE 11 — "ON" VOLTAGES

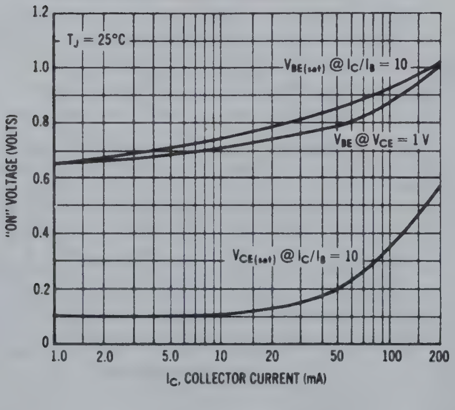
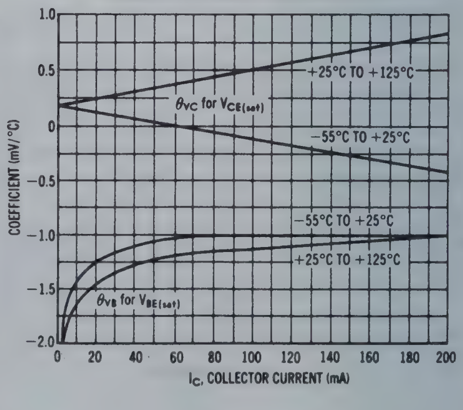


FIGURE 12 — TEMPERATURE COEFFICIENTS



2N4125 (SILICON)
2N4126

PNP silicon transistors designed for general purpose switching and amplifier applications and for complementary circuitry with NPN types 2N4123 and 2N4124 Features one-piece, injection-molded plastic package for high reliability.

CASE 29 (1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	2N4125	2N4126	Unit
Collector-Emitter Voltage	V_{CEO}	30	25	Vdc
Collector-Base Voltage	V_{CB}	30	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	350 2.73		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — CAPACITANCE

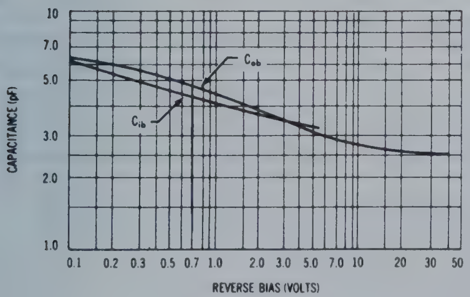
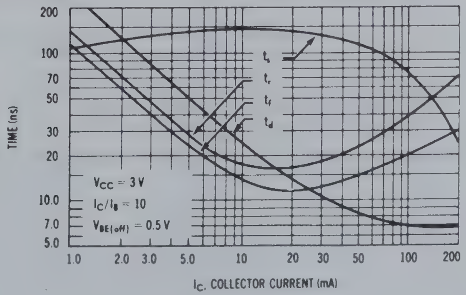


FIGURE 2 — SWITCHING TIMES



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage[1] (I_C = 1 mAdc, I_E = 0)	2N4125 2N4126		BV_{CEO}	30 25	– –	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N4125 2N4126		BV_{CBO}	30 25	– –	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)			I_{CBO}	–	50	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)			I_{EBO}	–	50	nAdc
ON CHARACTERISTICS						
DC Current Gain[1] (I_C = 2 mAdc, V_{CE} = 1 Vdc) (I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N4125 2N4126 2N4125 2N4126	9	h_{FE}	50 120 25 60	150 360 – –	–
Collector-Emitter Saturation Voltage[1] (I_C = 50 mAdc, I_B = 5 mAdc)		10, 11	$V_{CE(sat)}$	–	0.4	Vdc
Base-Emitter Saturation Voltage[1] (I_C = 50 mAdc, I_B = 5 mAdc)		11	$V_{BE(sat)}$	–	0.95	Vdc
SMALL SIGNAL CHARACTERISTICS						
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4125 2N4126		$\|h_{fe}\|$	2.0 2.5	– –	–
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4125 2N4126		f_T	200 250	– –	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)		1	C_{ob}	–	4.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		1	C_{ib}	–	10	pF
Small-Signal Current Gain (I_C = 2 mAdc, V_{CE} = 1 Vdc, f = 1 kHz)	2N4125 2N4126	5	h_{fe}	50 120	200 480	–
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1 k ohm, Noise Bandwidth = 10 Hz to 15.7 kHz)	2N4125 2N4126	3, 4	NF	– –	5.0 4.0	dB

SWITCHING CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Typ	Unit
Delay Time	V_{CC} = 3 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 10 mAdc; I_{B1} = 1 mAdc	2	t_d	25	ns
Rise Time		2	t_r	18	ns
Storage Time	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1 mAdc	2	t_s	140	ns
Fall Time		2	t_f	15	ns

[1] Pulse Test: Pulse Width = 300 μsec, Duty Cycle = 2%

AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 5 Vdc, T_A = 25°C

FIGURE 3 — FREQUENCY VARIATIONS

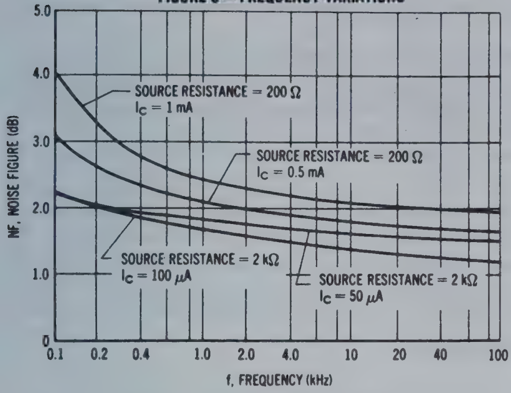
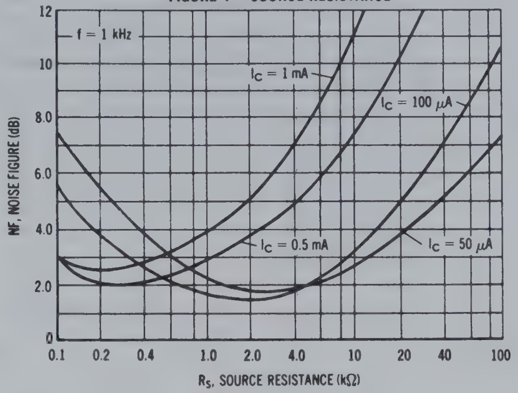


FIGURE 4 — SOURCE RESISTANCE



h PARAMETERS

V_{CE} = 10 V, f = 1 kHz, T_A = 25°C

FIGURE 5 — CURRENT GAIN

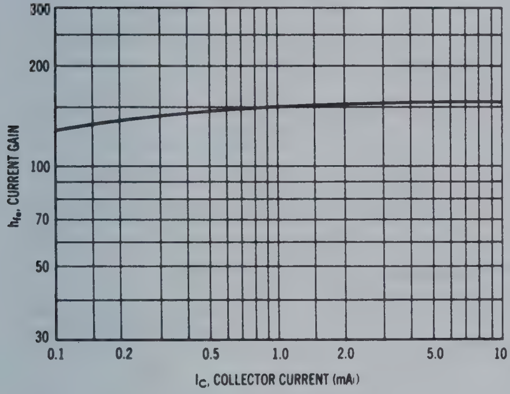


FIGURE 6 — OUTPUT ADMITTANCE

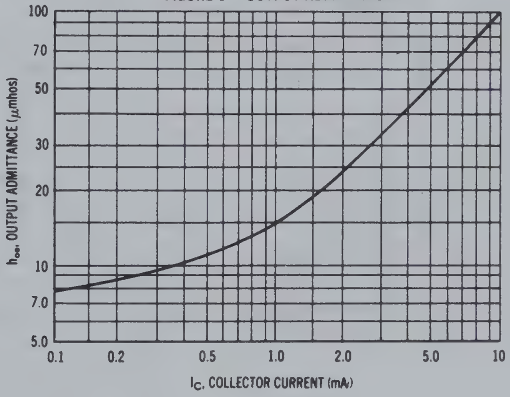


FIGURE 7 — INPUT IMPEDANCE

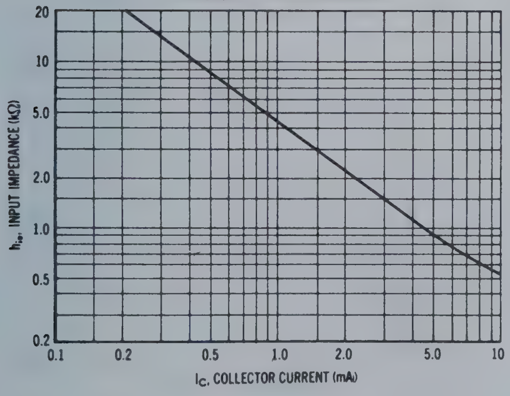
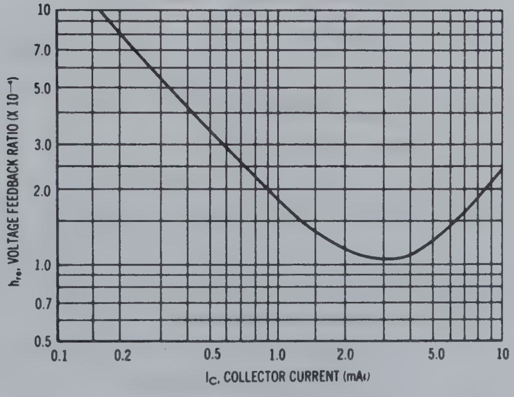


FIGURE 8 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 9 — NORMALIZED CURRENT GAIN

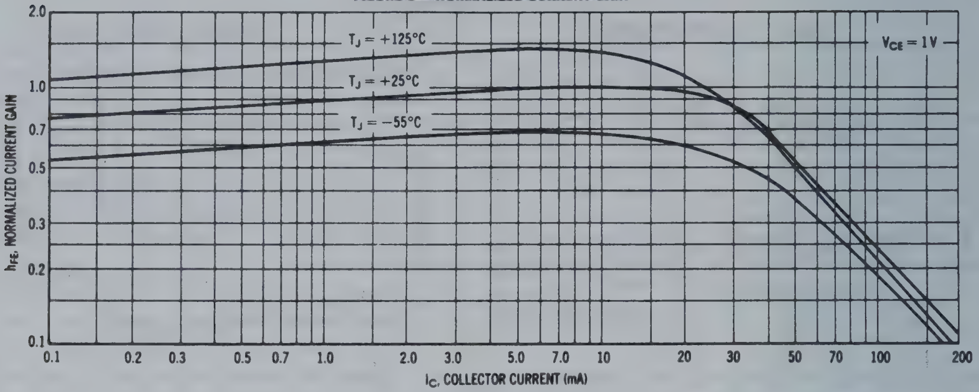


FIGURE 10 — COLLECTOR SATURATION REGION

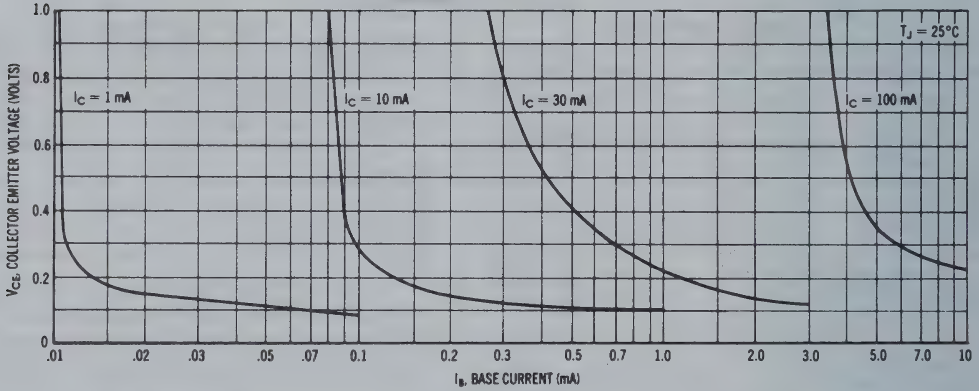


FIGURE 11 — "ON" VOLTAGES

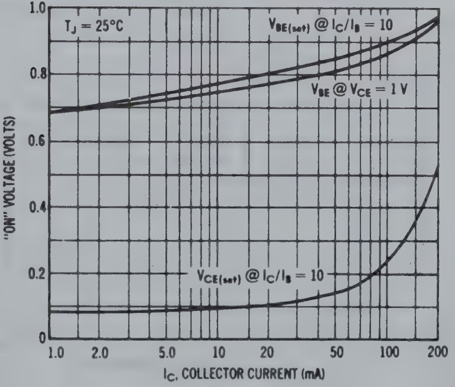
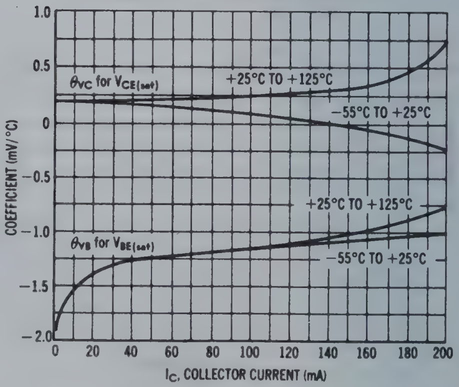


FIGURE 12 — TEMPERATURE COEFFICIENTS



2N4130 NPN (SILICON)

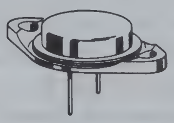
The RF Line

NPN SILICON RF POWER TRANSISTOR

. . . designed primarily for use in large-signal output amplifier stages. Intended for use in industrial communications equipment operating to 100 MHz. High breakdown voltages allow a high percentage of up-modulation in AM circuits operated at 28 volts.

- Balanced Emitter Construction
- Power Output – P_{out} = 50 W @ 70 MHz
- Collector-Base Voltage – 80 Vdc
- Case Common to Emitter

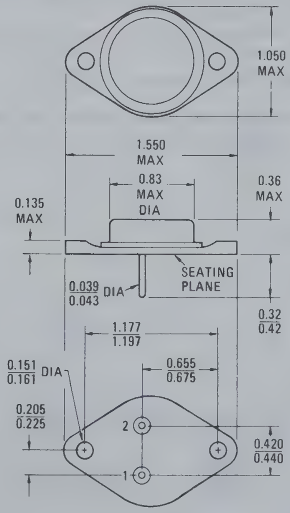
50 W - 70 MHz
RF POWER TRANSISTOR
NPN SILICON



*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	65	Vdc
Collector-Base Voltage	V_{CBO}	80	Vdc
Emitter-Base Voltage	V_{EBO}	4.0	Vdc
Collector Current – Continuous	I_C	10	Adc
Base Current – Continuous	I_B	2.0	Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	120 0.8	Watts W/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data


1.050
MAX
1.550
MAX
0.83
MAX
DIA
0.36
MAX
0.135
MAX
SEATING
PLANE
0.039
0.043
DIA
0.32
0.42
1.177
1.197
0.151
0.161
DIA
0.655
0.675
0.205
0.225
2
1
0.420
0.440

To convert inches to millimeters multiply by 25.4

PIN 1. BASE
2. COLLECTOR
Emitter connected to case

CASE 1

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 50 mAdc, I_B = 0)	$V_{CEO(sus)}$	65	–	–	Vdc
Collector-Emitter Sustaining Voltage (I_C = 50 mAdc, R_{BE} = 0)	$V_{CES(sus)}$	80	–	–	Vdc
Collector Cutoff Current	I_{CEV}				mAdc
(V_{CE} = 75 Vdc, V_{BE} = −1.5 Vdc)		–	–	0.2	
(V_{CE} = 50 Vdc, V_{BE} = −1.5 Vdc, T_C = 150°C)		–	–	1.0	
Collector Cutoff Current (V_{CB} = 80 Vdc, I_E = 0)	I_{CBO}	–	–	0.02	mAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	–	–	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain(1)	h_{FE}				–
(I_C = 2.0 Adc, V_{CE} = 5.0 Vdc)		10	–	60	
(I_C = 10 Adc, V_{CE} = 5.0 Vdc)		10	–	–	
Collector-Emitter Saturation Voltage(1) (I_C = 10 Adc, I_B = 2.0 Adc)	$V_{CE(sat)}$	–	–	2.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product(2) (I_C = 2.0 Adc, V_{CE} = 10 Vdc, f = 50 MHz)	f_T	125	–	–	MHz
Output Capacitance (V_{CB} = 28 Vdc, I_E = 0, f = 0.13 MHz)	C_{ob}	–	125	200	pF
FUNCTIONAL TEST (Figure 1)					
Power Input (Figure 1) (P_{out} = 50 W, R_S = 50 Ohms, V_{CE} = 28 Vdc, f = 70 MHz)	P_{in}	–	–	8.0	Watts
Collector Efficiency (P_{out} = 50 W, R_S = 50 Ohms, V_{CE} = 28 Vdc, f = 70 MHz)	η	50	–	–	%

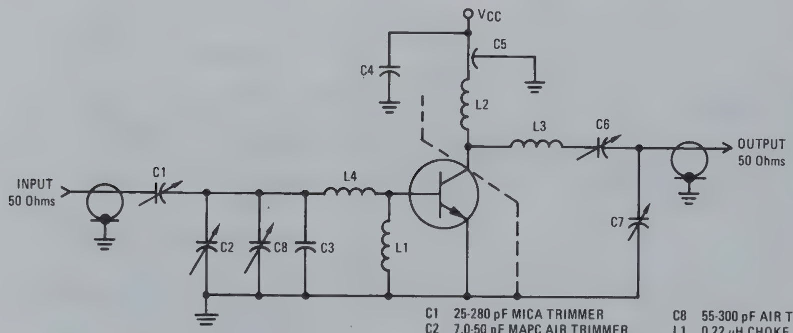
*Indicates JEDEC Registered Data

Notes:

(1)Pulse Test: Pulse Width ≦ 100 μs, Duty Cycle = 1.0%.

(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

FIGURE 1 – 70 MHz POWER GAIN TEST CIRCUIT



C1	25-280 pF MICA TRIMMER
C2	7.0-50 pF MAPC AIR TRIMMER
C3	200 pF MICA CAPACITOR
C4	0.005 μF CERAMIC CAPACITOR
C5	1500 pF FEEDTHRU CAPACITOR
C6,C7	24-200 pF MICA TRIMMER
C8	55-300 pF AIR TRIMMER
L1	0.22 μH CHOKE
L2	0.1 μH CHOKE
L3	2 TURNS, #14 AWG, 1" DIA., 1/4" LONG
L4	3/4" LONG, 1/4" WIDE, 0.3" THICK COPPER STRAP

2N4151 (SILICON)
thru
2N4198

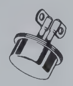
SILICON CONTROLLED RECTIFIERS

8-AMPERE RMS
25 thru 600 VOLTS

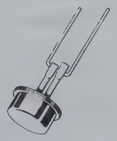
THYRISTORS

. . . multi-purpose PNPN silicon controlled rectifiers suited for industrial, consumer, and mulitary applications. Offered in a choice of space-saving, economical packages for mounting versatility.

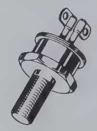
- Uniform Low-Level Noise-Immune Gate Triggering — I_{GT} = 10 mA (Typ) @ T_C = 25°C
- Low Forward "On" Voltage — v_T = 1.0 V (Typ) @ 5.0 Amp @ 25°C
- High Surge-Current Capability — I_{TSM} = 100 Amp Peak
- Fatigue-Free Solder Construction
- Shorted Emitter Construction



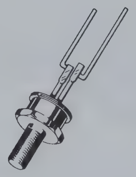
2N4151-58
CASE 85



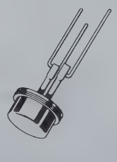
2N4159-66
CASE 85L



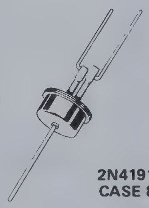
2N4167–74
CASE 86



2N4175-82
CASE 86L



2N4183-90
CASE 87L



2N4191-98
CASE 88L

MAXIMUM RATINGS

(Apply over operating temperature range and for all case types unless otherwise noted)

Rating	Symbol	Value	Unit
*Peak Reverse Blocking Voltage (1)	V_{RRM}		Volts
2N4151, 59, 67, 75, 83, 91		25	
2N4152, 60, 68, 76, 84, 92		50	
2N4153, 61, 69, 77, 85, 93		100	
2N4154, 62, 70, 78, 86, 94		200	
2N4155, 63, 71, 79, 87, 95		300	
2N4156, 64, 72, 80, 88, 96		400	
2N4157, 65, 73, 81, 89, 97		500	
2N4158, 66, 74, 82, 90, 98		600	
Forward Current RMS	$I_{T(RMS)}$	8.0	Amp
*Peak Forward Surge Current (One cycle, 60 Hz, T_J = -40 to +100°C)	I_{TSM}	100	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C; $t \leqq 8.3$ ms)	I^2t	40	A^2s
*Peak Gate Power	P_{GM}	5.0	Watt
*Average Gate Power	$P_{G(AV)}$	0.5	Watt
*Peak Gate Current	I_{GM}	2.0	Amp
Peak Gate Voltage (2)	V_{GM}	10	Volts
*Operating Temperature Range	T_J	-40 to +100	°C
*Storage Temperature Range	T_{stg}	-40 to +150	°C
Stud Torque 2N4167-2N4182		15	in. lb.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Thermal Resistance, Junction to Case	$R\theta_{JC}$	1.5	2.5*	°C/W
Thermal Resistance, Case to Ambient (See Fig. 11) 2N4151-66, 2N4183-98	$R\theta_{CA}$	50	–	°C/W

(1) Ratings apply for zero or negative gate voltage. Devices should not be tested for blocking capability in a manner such that the voltage applied exceeds the rated blocking voltage.
(2) Devices should not be operated with a positive bias applied to the gate concurrently with a negative potential applied to the anode.
*Indicates JEDEC Registered Data

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
*Peak Forward Blocking Voltage (1) (T_J = 100°C)	2N4151, 59, 67, 75, 83, 91	V_{DRM}	25	–	–	Volts
	2N4152, 60, 68, 76, 84, 92		50	–	–	
	2N4153, 61, 69, 77, 85, 93		100	–	–	
	2N4154, 62, 70, 78, 86, 94		200	–	–	
	2N4155, 63, 71, 79, 87, 95		300	–	–	
	2N4156, 64, 72, 80, 88, 96		400	–	–	
	2N4157, 65, 73, 81, 89, 97		500	–	–	
	2N4158, 66, 74, 82, 90, 98		600	–	–	
*Peak Forward Blocking Current (Rated V_{DRM} @ T_J = 100°C, gate open)		I_{DRM}	–	–	2.0	mA
*Peak Reverse Blocking Current (Rated V_{DRM} @ T_J = 100°C, gate open)		I_{RRM}	–	–	2.0	mA
Gate Trigger Current (Continuous dc) (2)		I_{GT}				mA
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω)			–	–	30	
*(Anode Voltage = 7.0 Vdc, R_L = 100 Ω T_C = –40°C)			–	–	60	
Gate Trigger Voltage (Continuous dc)		V_{GT}				Volts
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω)			–	–	1.5	
*(Anode Voltage = 7.0 Vdc, R_L = 100 Ω, T_C = –40°C)			–	–	2.5	
*(Anode Voltage = 7.0 Vdc, R_L = 100 Ω, T_J = 100°C)			0.2	–	–	
*Forward "On" Voltage (pulsed, 1.0 ms max, duty cycle ≤ 1%) (I_F = 15.7 A)		V_T	–	–	2.0	Volts
Holding Current		I_H				mA
(Anode Voltage = 7.0 Vdc, gate open)			–	–	30	
*(Anode Voltage = 7.0 Vdc, gate open, T_C = –40°C)			–	–	60	
Turn-On Time ($t_d + t_r$) (I_G = 20 mAdc, I_F = 5.0 Adc)		t_{on}	–	1.0	–	μs
Turn-Off Time		t_{off}				μs
(I_F = 5.0 Adc, I_R = 5.0 Adc)			–	15	–	
(I_F = 5.0 Adc, I_R = 5.0 Adc, T_J = 100°C) (V_{FXM} = rated voltage) (dv/dt = 30 V/μs)			–	25	–	
Forward Voltage Application Rate (Gate open, T_J = 100°C)		dv/dt	–	50	–	V/μs

(1) Ratings apply for zero or negative gate voltage. These devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

(2) For optimum operation, i.e. faster turn-on, lower switching losses, best di/dt capability, recommended I_{GT} = 200 mA minimum.

*Indicates JEDEC Registered Data

TYPICAL TRIGGER CHARACTERISTICS

FIGURE 1 – CONSTANT CURRENT TRIGGERING

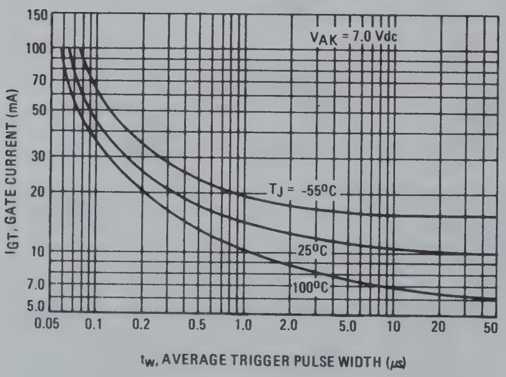
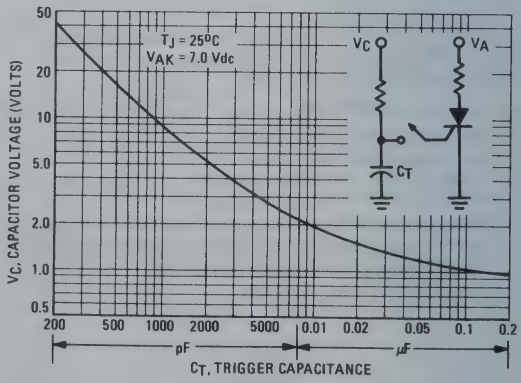


FIGURE 2 – CAPACITIVE DISCHARGE TRIGGERING



CURRENT DERATING

FIGURE 3 – MAXIMUM CASE TEMPERATURE

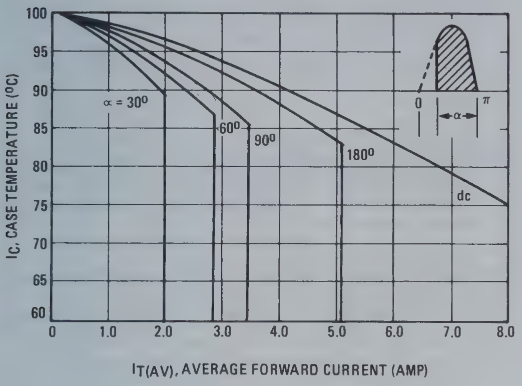


FIGURE 4 – MAXIMUM AMBIENT TEMPERATURE

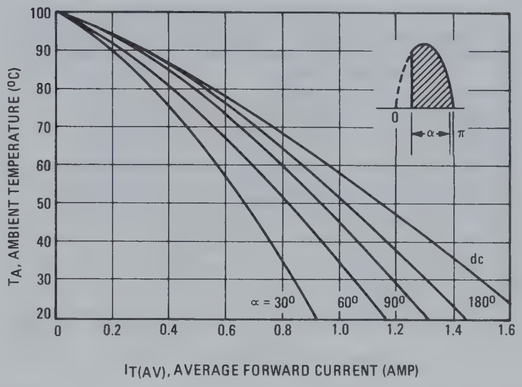


FIGURE 5 – FORWARD POWER DISSIPATION

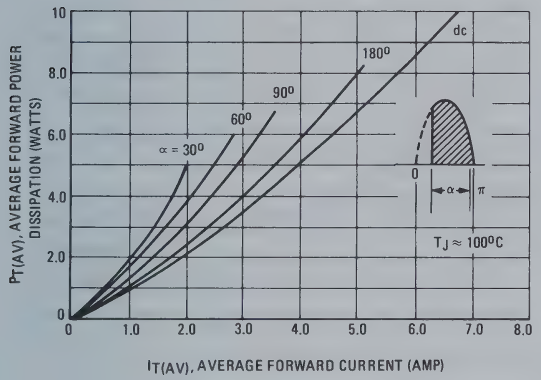


FIGURE 6 – MAXIMUM SURGE CAPABILITY

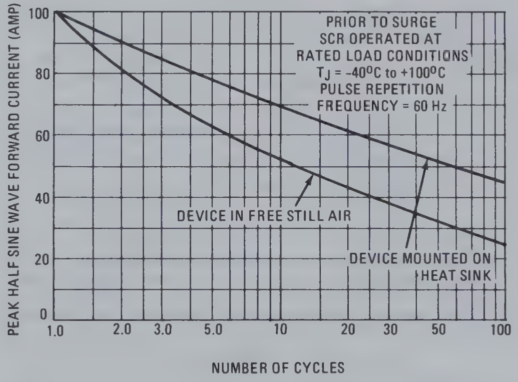


FIGURE 7 – THERMAL RESPONSE

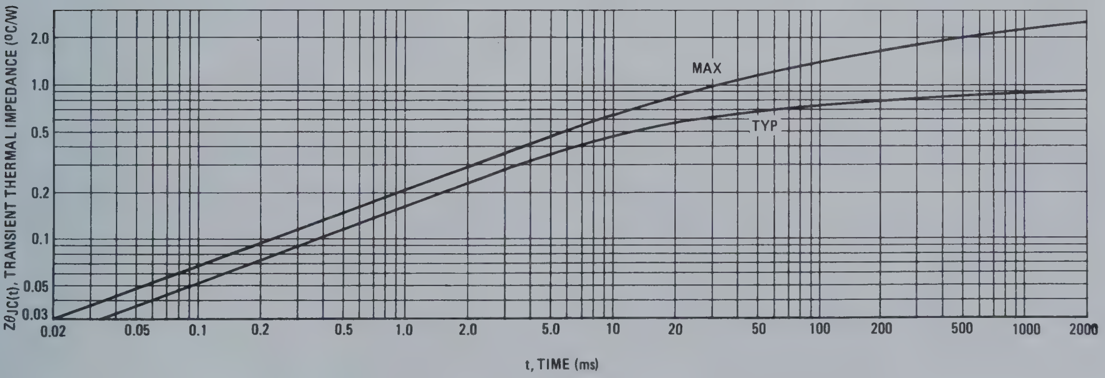


FIGURE 8 – FORWARD VOLTAGE

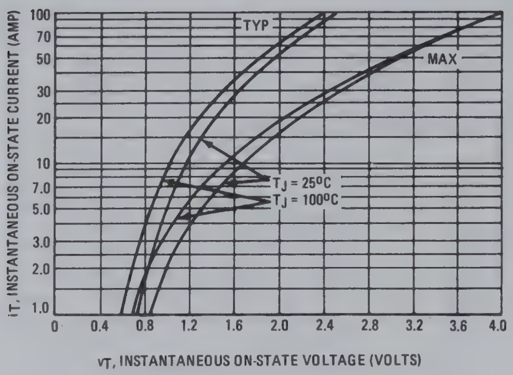


FIGURE 9 – HOLDING CURRENT

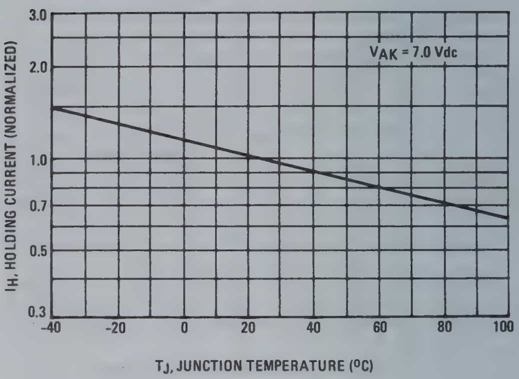


FIGURE 10 – TYPICAL THERMAL RESISTANCE OF PLATES

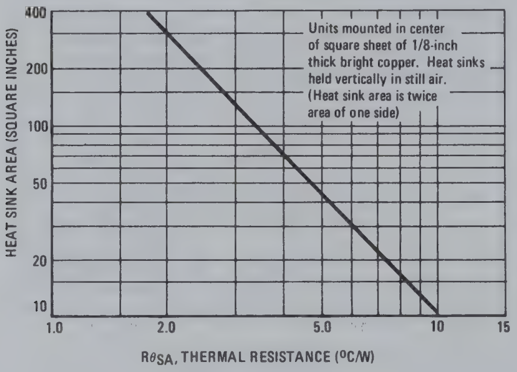
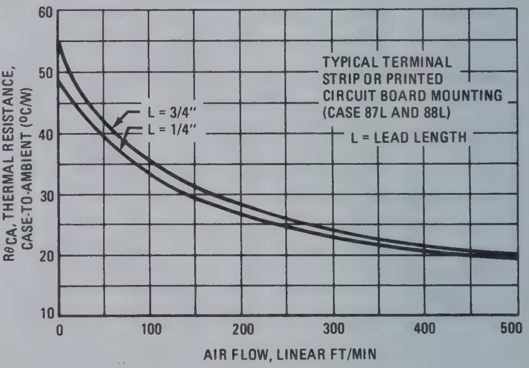


FIGURE 11 – CASE-TO-AMBIENT THERMAL RESISTANCE



MOUNTING and THERMAL INFORMATION

The versatility of the Motorola SCR can-type package affords a variety of mounting methods to meet individual requirements. Depending upon the thermal resistance value between the SCR case and a heat sink, any mounting method which satisfies the current derating curves may be used. Possible mounting media include: solder, epoxy cements; clips (fuse, resistor, transistor, special); clamps; commercial or special dissipators, retainers, coolers, and radiators.

When mounting the SCR's to a heat sink, the following recommendations apply:

A. Heat Sink Contact

1. Since the silicon die is located in the case bottom, (opposite end from tubed header point A as shown on the mechanical outline drawing, Figure 12.) the heat sink contact should be made with case bottom for proper heat transfer.

B. General Soldering Precautions

1. Solder — Use solder with melting points between +175°C and +225°C. The commonly-used tin-lead alloy solders have melting points of +188°C (60/40 alloy) and +214°C (50/50 alloy).
2. Flux (when used) — Non-corrosive resin preferred.
3. When soldering to the device terminals or leads, use of a heat dissipator between soldering point and SCR case is recommended.

C. Case Soldering Methods

1. Heat Sink Materials:
    a. Copper and most of its alloys present no problem in soldering and would probably be the most favorable heat sink material.
    b. Stainless steel is difficult to solder. However, using a strong acid-filled solder, satisfactory soldering can be achieved.
    c. In most cases where soldering is difficult, such as with aluminum, proper preparation with a tin coating on the material can bring about good results.

Depending on specific needs, soldering can be effected by using either hot plate, oven, or belt feed furnace. In all cases, temperature must be controlled.

2. Hot Plate — The hot plate is probably the most effective and flexible method of soldering. The following method is recommended:
    a. Set surface temperature of hot plate to a maximum of 225°C.
    b. Place heat sinks on hot plate for approximately 5 minutes.
    c. Place ⅛"-¼" diameter solder preform on area of heat sink to be soldered.
    d. After solder becomes liquid, place device on this area applying slight pressure and rotating the device slightly to assure good contact. Flux may be used here if required. Frequently, suitable wetting can be achieved mechanically when the device is rotated in the liquid solder, depending upon the device surface conditions.
    e. Remove heat sinks from heat source and free air cool.
3. Oven — When soldering is performed in an oven, use a solder preform (disc, 0.300" x 0.010") or flatten solder wire (⅛"-¼") before placing it on the heat sink. For an inert atmosphere such as N_2, dry air, etc., a flux is recommended. If H_2N_2 is available and used, flux should not be required. Again, temperature must be controlled.
4. Belt Feed Furnace — The procedures are much the same as with the oven method, with the exception that possibly a jig would be required to hold the device and the heat sink in the proper position.

D. Epoxy Mounting Suggestions

1. There are many good commercial epoxies available today, such as Hysol's "HY-TAC" kit or 3M's "Scotch Cast #9". Suitable mounting may be obtained by following the epoxy manufacturer's recommendations for mixing and then cementing the thyristor to the mounting surface with a slight pressure and rotary movement. If improved thermal conductivity is desired, powdered alumina (325 mesh) may be mixed into the epoxy in a proportion of 70% (epoxy) to 30% (alumina). If electrical insulation is desired between the thyristor and a heat-sink, thin fiberglass tape (course surface) or mica discs may be used.

The primary reason for specifying mounting details is to help maintain the junction temperature of the SCR at a safe level and hence provide satisfactory operation. The fundamental relationship between junction temperature and heat sinks can be expressed as follows:

$$T_J = T_A + R\theta_{JA} P_D$$

where:

T_J = junction temperature (100°C max operating for these devices)
T_A = ambient temperature
$R\theta_{JA}$ = junction-to-ambient thermal resistance
= $R\theta_{JC} + R\theta_{CA}$ (with $R\theta_{CA} = R\theta_{CS} + R\theta_{SA}$ when heat sink used)
$R\theta_{JC}$ = junction-to-case thermal resistance
$R\theta_{CA}$ = case-to-ambient thermal resistance
$R\theta_{CS}$ = case-to-heat sink thermal resistance
$R\theta_{SA}$ = heat sink-to-ambient thermal resistance
P_D = average power dissipated in the SCR

It is more accurate to base circuit designs upon the case temperature. The preferred method to determine case temperature is to place a thermocouple on the package at point A as shown on the mechanical outline drawing, Figure 12. Even when used in free air, the mass of the package is large enough so that it will not respond to heat surges generated at a 60 Hz rate or higher once steady-state conditions are achieved.

For operation with a heat sink, normally, the $R\theta_{CS}$ portion of $R\theta_{CA}$ will range between 0.2 and 1°C/W for the can type SCR's, depending upon the particular mounting. $R\theta_{CA}$ is approximately 0.2°C/W for the stud packages when used with a thermal grease. Likewise, the $R\theta_{SA}$ portion of $R\theta_{CA}$ will vary with the shape, material, and configuration of the heat sink as well as with the surrounding conditions. Figure 10 is a very basic guide to $R\theta_{SA}$.

For free air operation, in instances where the case temperature cannot be measured or for preliminary engineering work, the case temperature can be estimated by using values of case-to-ambient thermal resistance, obtained from Figure 11 and the relation:

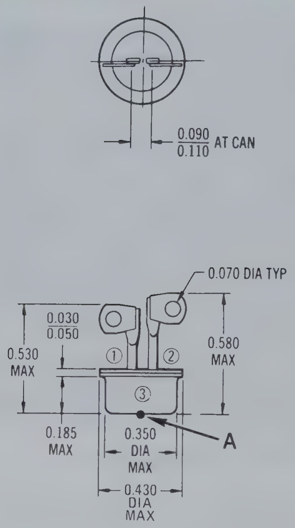
$$T_C = R\theta_{CA} P_D + T_A$$

The graph of Figure 11 indicates that the lead length of the SCR and the thermal mass of the connection to the lead will influence the value of $R\theta_{CA}$.

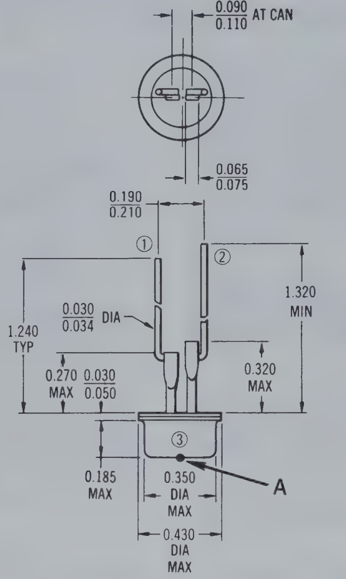
For convenience, Figure 4 shows derating information when the parts are in a still air ambient mounted on a typical P.C. board.

FIGURE 12 – OUTLINE DIMENSIONS

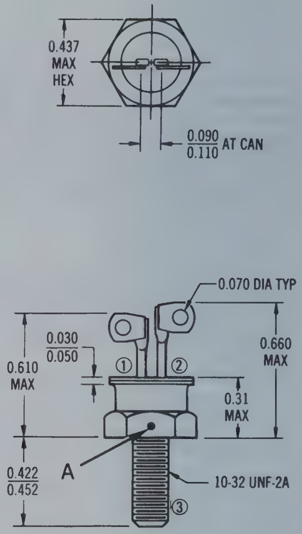
2N4151-58
CASE 85


0.090/0.110 AT CAN
0.070 DIA TYP
0.030/0.050
0.530 MAX
①
②
0.580 MAX
③
0.185 MAX
0.350 DIA MAX
A
0.430 DIA MAX

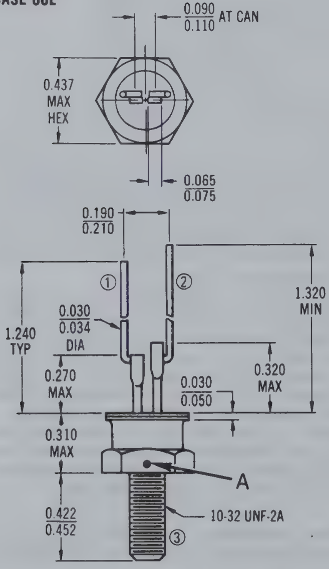
2N4159-66
CASE 85L


0.090/0.110 AT CAN
0.065/0.075
0.190/0.210
①
②
1.320 MIN
0.030/0.034 DIA
1.240 TYP
0.270 MAX
0.030/0.050
0.320 MAX
③
0.185 MAX
0.350 DIA MAX
A
0.430 DIA MAX

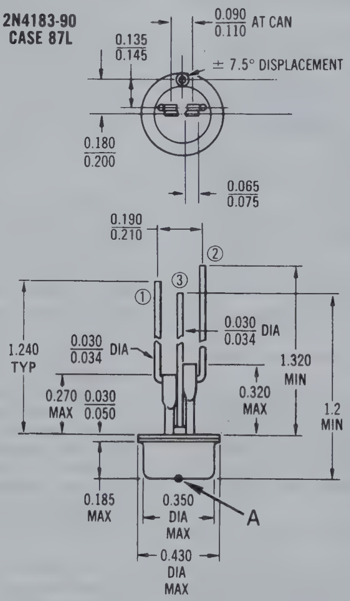
2N4167-74
CASE 86


0.437 MAX HEX
0.090/0.110 AT CAN
0.070 DIA TYP
0.030/0.050
0.610 MAX
①
②
0.660 MAX
0.31 MAX
0.422/0.452
A
10-32 UNF-2A
③

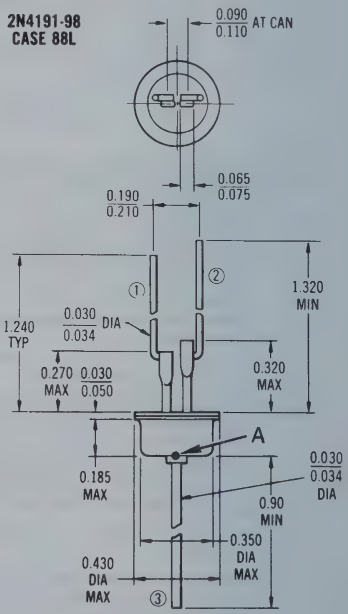
2N4175-82
CASE 86L


0.090/0.110 AT CAN
0.437 MAX HEX
0.065/0.075
0.190/0.210
①
②
1.320 MIN
0.030/0.034 DIA
1.240 TYP
0.270 MAX
0.030/0.050
0.320 MAX
0.310 MAX
A
0.422/0.452
10-32 UNF-2A
③

2N4183-90
CASE 87L


0.090/0.110 AT CAN
0.135/0.145
± 7.5° DISPLACEMENT
0.180/0.200
0.065/0.075
0.190/0.210
②
③
①
0.030/0.034 DIA
1.240 TYP
0.030/0.034 DIA
1.320 MIN
0.270 MAX
0.030/0.050
0.320 MAX
1.2 MIN
0.185 MAX
0.350 DIA MAX
A
0.430 DIA MAX

2N4191-98
CASE 88L


0.090/0.110 AT CAN
0.065/0.075
0.190/0.210
①
②
1.320 MIN
1.240 TYP
0.030/0.034 DIA
0.270 MAX
0.030/0.050
0.320 MAX
A
0.185 MAX
0.030/0.034 DIA
0.90 MIN
0.350 DIA MAX
0.430 DIA MAX
③

LEAD	STYLE 1 (Thyristors)
①	GATE
②	CATHODE
③	ANODE

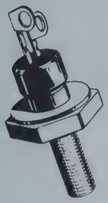
NOTES:

1. The case (anode) leads for the 2N4183-90 and 2N4191-98 series may be attached by either soldering or welding techniques.

2. On all package types: Manufacturer may optionally use a small metal tab on the case perimeter opposite the gate terminal for terminal identification purposes.

3. Point A indicates temperature reference point

2N4199 thru 2N4204 (SILICON)



CASE 63

Fast switching, high-voltage thyristors especially designed for pulse modulator applications in radar and other similar equipment. Available as JAN devices.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage* (T_J=105°C)	$V_{ROM(rep)}$*	50	Volts
Repetitive Peak Forward Current (PW = 3.0 μs, Duty Cycle = 0.6%, T_C = 85°C max)	$I_{FM(rep)}$	100	Amp
Current Application Rate**	di/dt**	5000	A/μs
Peak Gate Power-Forward	P_{GFM}	20	Watts
Average Gate Power-Forward	$P_{GF(AV)}$	1.0	Watt
Peak Gate Current-Forward	I_{GFM}	5.0	Amp
Peak Gate Voltage-Forward Reverse ***	V_{GFM} V_{GRM} ***	10 10	Volts
Operating Junction Temperature Range Blocking State Conducting State	T_J	 -65 to +105 -65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Stud Torque	—	15	in. lb.

*Characterized for unilateral applications where reverse blocking capability is not important. Higher voltage units available upon request. $V_{ROM(rep)}$ may be applied as a continuous d c voltage for zero or negative gate voltage but positive gate voltage must not be applied concurrently with a negative potential on the anode. When checking blocking capability, do not permit the applied voltage to exceed the rated voltage.

**Minimum Gate Trigger Pulse: $i_G = 200$ mA, PW = 1 μs, $t_r = 20$ ns.

***Do not reverse bias gate during forward conduction if anode current exceeds 10 amperes.

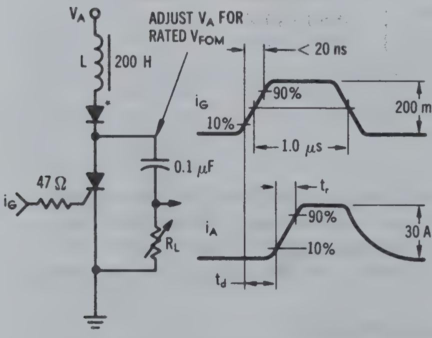
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage* ($T_C = 105°C$)	2N4199	15	V_{FOM}*	300	—	Volts
	2N4200			400	—	
	2N4201			500	—	
	2N4202			600	—	
	2N4203			700	—	
	2N4204			800	—	
Peak Forward and Reverse Blocking Current (Rated V_{FOM} and V_{ROM}, $T_C = 105°C$, gate open)		17	I_{FOM}	—	2.0	mA
			I_{ROM}	—	2.0	
Gate Trigger Current (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = 25°C$)		14	I_{GT}	—	50	mA
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = -65°C$)				—	100	
Gate Trigger Voltage (Continuous dc) (Anode Voltage = rated V_{FOM}, R_L = 100 ohms, $T_C = 105°C$)		12	V_{GT}	0.2	—	Volts
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = 25°C$)				—	1.5	
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = -65°C$)				—	2.0	
Holding Current (Anode Voltage = 7.0 Vdc, gate open, $T_C = 105°C$)		18	I_{HO}	3.0	—	mA
Forward "On" Voltage (I_f = 2 Adc, PW = 1.0 ms max, Duty cycle ≤ 1%)		8	V_F	—	1.5	Volts
Dynamic Forward "On" Voltage (0.5 µs after 50% decay point on dynamic forward voltage waveform.) Forward Current: 30 A pulse (PFN discharge circuit.) Gate Pulse: at 200 mA, PW = 1.0 µs, t_r = 20 ns		7	$V_{F(on)}$	—	25	Volts
Turn-On Time Delay Time	All types	1, 9	t_d	—	200	ns
Rise Time	2N4199 and 2N4200	1, 11	t_r	—	200	
	2N4201			—	150	
	2N4202			—	130	
	2N4203 and 2N4204			—	100	
Pulse Turn-Off Time Test Conditions: PFN discharge; Forward Current = 30 A pulse; Reverse Current = 5.0 A, $T_C = 85°C$, dv/dt = 250 V/µs to Rated V_{FOM}; Reverse anode voltage during turn-off interval = 0 V; Reverse gate bias during turn-off interval = 6.0 V.		2, 13	$t_{off(pulse)}$	—	20	µs
Forward Voltage Application Rate (Linear Rise of Voltage) ($T_C = 105°C$, gate open)		16	dv/dt	250	—	V/µs
Thermal Resistance (Junction to Case)		6	θ_{JC}	—	3.0	°C/W

*V_{FOM} for all types can be applied on a continous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. When checking forward or reverse blocking capability, these devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage. Other voltage units available upon request.

TEST CIRCUITS

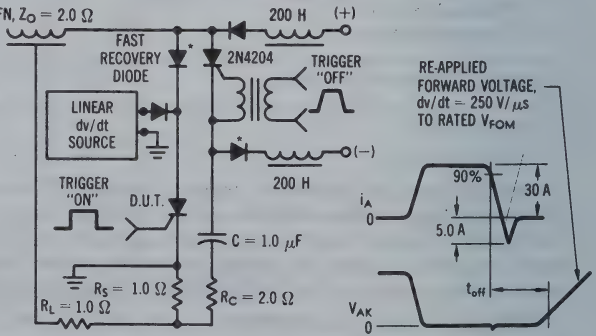
FIGURE 1 — TURN-ON TIME



V_A
ADJUST V_A FOR RATED V_{FOM}
< 20 ns
L
200 H
*
i_G
90%
10%
200 mA
1.0 µs
0.1 µF
47 Ω
i_G
t_r
90%
i_A
10%
30 A
R_L
t_d

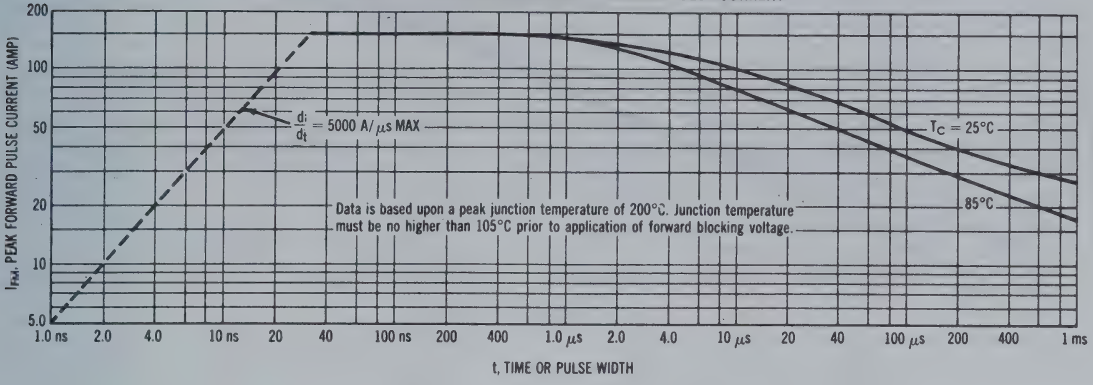
*Two MR1337-5 fast-recovery diodes in series

FIGURE 2 — TURN-OFF TIME



PFN, Z_O = 2.0 Ω
200 H
(+)
FAST RECOVERY DIODE
*
2N4204
TRIGGER "OFF"
LINEAR dv/dt SOURCE
RE-APPLIED FORWARD VOLTAGE, dv/dt = 250 V/µs TO RATED V_{FOM}
*
(−)
200 H
TRIGGER "ON"
D.U.T.
90%
30 A
i_A
0
5.0 A
C = 1.0 µF
R_S = 1.0 Ω
R_C = 2.0 Ω
R_L = 1.0 Ω
t_{off}
V_{AK}
0

FIGURE 3 — MAXIMUM ALLOWABLE FORWARD PULSE CURRENT



CURRENT DERATING DATA

FIGURE 4 — DERATING USING NO SWITCHING LOSSES

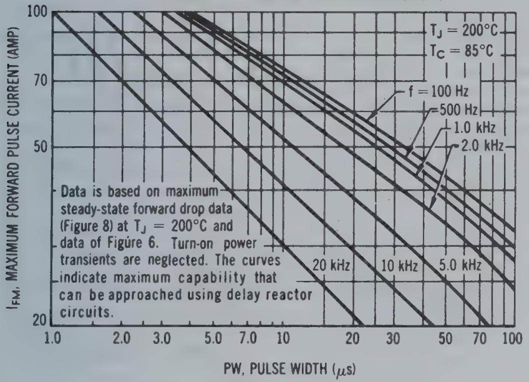
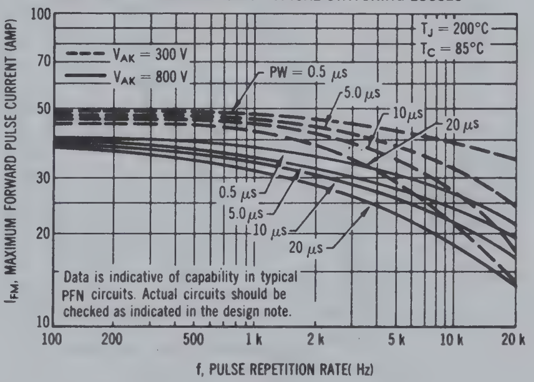


FIGURE 5 — DERATING USING TYPICAL SWITCHING LOSSES



DESIGN NOTE

Use of Transient Thermal Resistance Data

A train of periodical power pulses can be represented by the model shown in Fig. A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Fig. 6 was calculated for various duty cycles from:

$$r(t) = D + (1 - D) \cdot r(t_A + t_p) + r(t_A) - r(t_p)$$

To find $\theta_{JC}(t)$ multiply the value obtained from Fig. 6 by the steady-state value $\theta_{JC}(\infty)$. Use 3°C/W for worst-case results; use 2°C/W for typical information.

DESIGN EXAMPLE

A 2N4199 discharging a PFN, transient power pulse shown in Fig. C.

Conditions: $V_{AK} = 150$ V., $I_{PK} = 44$ A., f = 5000 Hz.

Determine: ΔT

Method 1: (See Fig. A) $P_A t_A$ is chosen to have the same energy as the actual power pulse, i.e.: the area under the curves are equal. P_A equals the peak of the actual power pulse. At a pulse repetition frequency of 5000 Hz and $T_A = 2.14$ µs (D = 0.0107); the reading on Fig. 6 is 0.039.

$$\therefore \Delta T = r(t)\theta_{JC}(\infty) P_A = (0.039)(3)(1000) = 120°C.$$

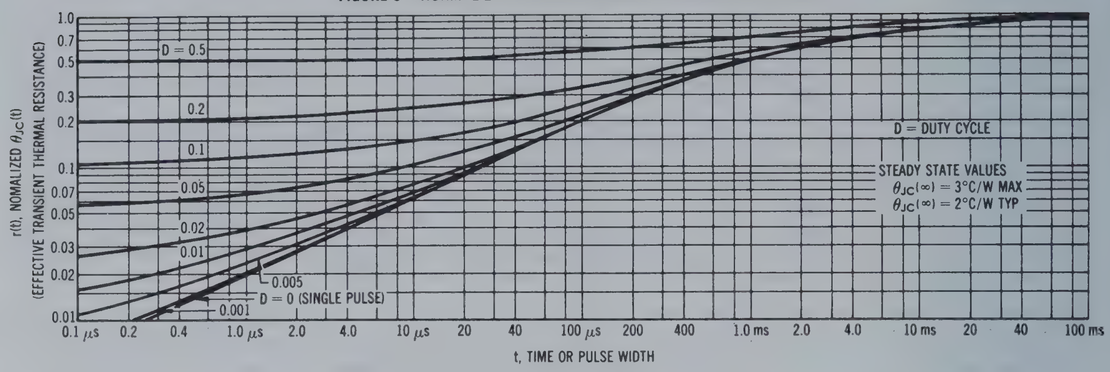
Method 2: For a power waveform where the time of the peak power is short compared to the total transient, the foregoing method results in an overly large safety factor. A pulse model closer to the real case is shown in Fig. B. Using the transient thermal resistance information for D = 0 in Fig. 6, $\Delta T(t_4)$ and $\Delta T(t_5)$ can be evaluated from

$$\Delta T(t_4) = \Big[P_1\,[r(T_1) + (1 - D_1) \cdot r(T + T_1) + D - r(T)] + P_2[(1 - D_2) \cdot r(T) + D_2 - r(T - T_2)]\Big]\,\theta_{JC}(\infty)$$

$$\Delta T(t_5) = \Big[P_1[r(T_1 + T_2) + (1 - D_1) \cdot r(T + T_1 + T_2) - r(T + T_2) - r(T_2)] + P_2[r(T_2) + (1 - D_2 \cdot r(T + T_2) + D_2 - r(T)]\Big]\,\theta_{JC}(\infty)$$

The two results are compared; the one with higher value is taken for worst-case design. For the problem, values for the equivalent pulses of Fig. B are $P_1 = 1000$ W, $P_2 = 700$ W, $T_1 = 1.05$ µs, $T_2 = 1.55$ µs, $D_1 = 5.25(10^{-3})$, $D_2 = 7.75(10^{-3})$.

FIGURE 6 — NORMALIZED EFFECTIVE TRANSIENT THERMAL RESISTANCE



FORWARD "ON" VOLTAGE DATA

FIGURE 7 — TYPICAL DYNAMIC FORWARD "ON" VOLTAGE

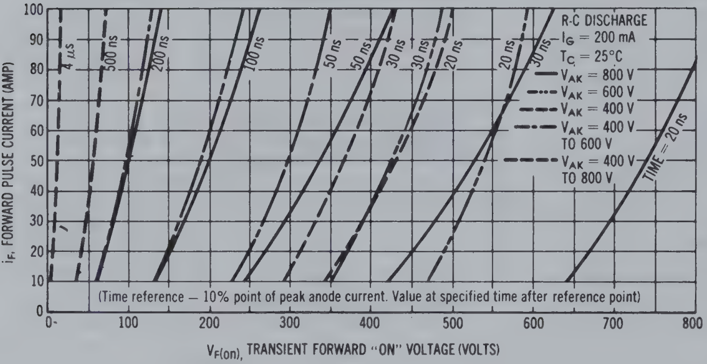
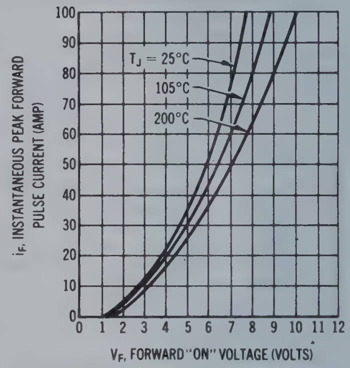


FIGURE 8 — MAXIMUM STEADY-STATE



$$\Delta T(t_4) = \Big[1000\,[0.0205 + (1-5.25\cdot10^{-3})\,0.27 + 5.25\cdot10^{-3} - 0.27] + 700\,[(1-7.75\cdot10^{-3})\,0.27 + 7.75\cdot10^{-3} - 0.27]\Big]\,3 = 93.51°\mathrm{C}$$

$$\Delta T(t_5) = \Big[1000\,[0.032 + (1-5.25\cdot10^{-3})\,0.27 + 5.25\cdot10^{-3} - 0.27 - 0.0205] + 700\,[0.025 + (1-7.75\cdot10^{-3})\,0.27 + 7.75\cdot10^{-3} - 0.27]\Big]\,3 = 105.6°\mathrm{C}$$

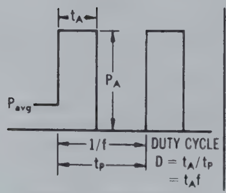

tA
PA
Pavg
1/f
tP
DUTY CYCLE
D = tA/tP
= tAf

FIGURE A — SIMPLE MODEL

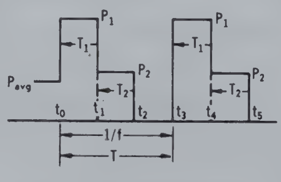

P1
T1
P2
T2
Pavg
P1
T1
P2
T2
t0
t1
t2
t3
t4
t5
1/f
T

FIGURE B — MORE ACCURATE MODEL

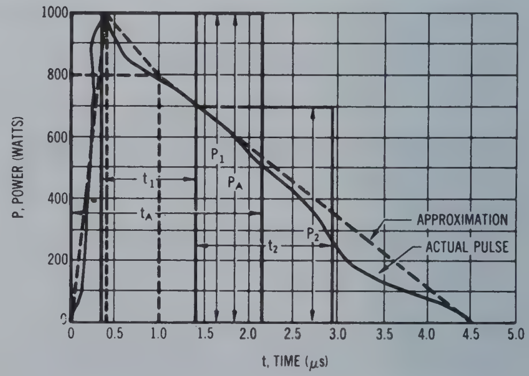


FIGURE C — AN ACTUAL TRANSIENT POWER PULSE

SWITCHING CHARACTERISTICS

FIGURE 9 — DELAY TIME

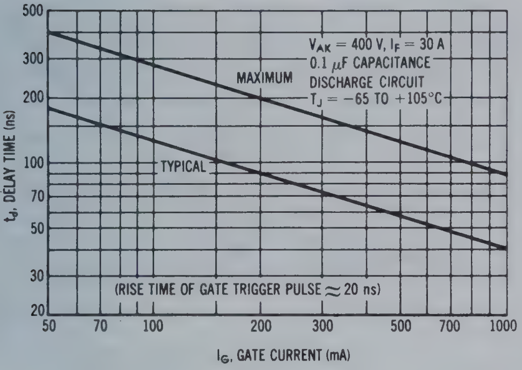


FIGURE 11 — CURRENT RISE TIME

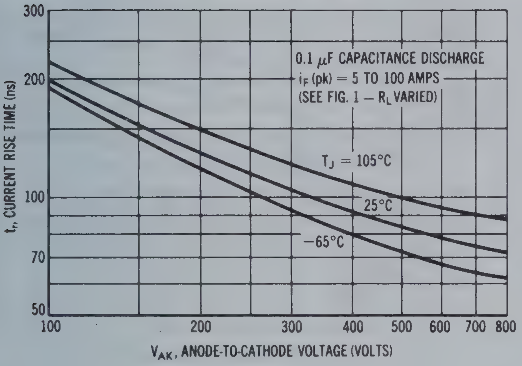
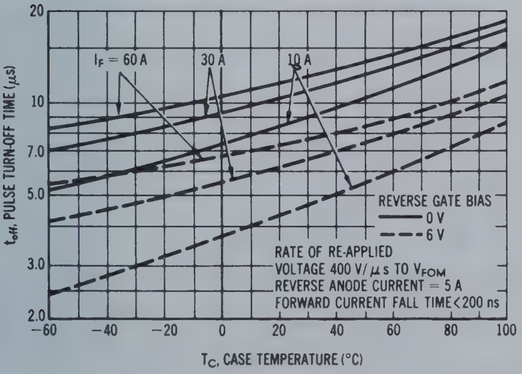


FIGURE 13 — TYPICAL TURN-OFF TIME



TRIGGERING CHARACTERISTICS

FIGURE 10 — TYPICAL PULSE TRIGGER CHARGE/CURRENT

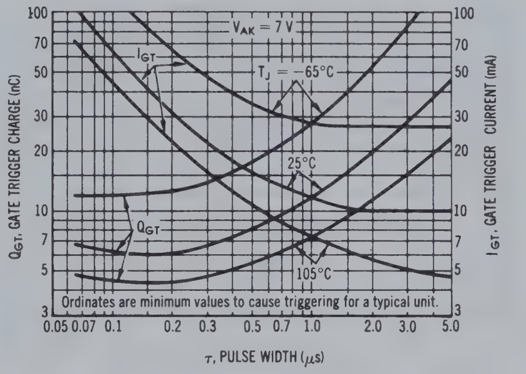


FIGURE 12 — DC GATE TRIGGER VOLTAGE

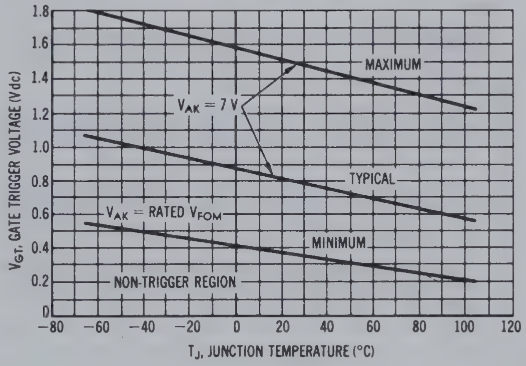


FIGURE 14 — DC GATE TRIGGER CURRENT

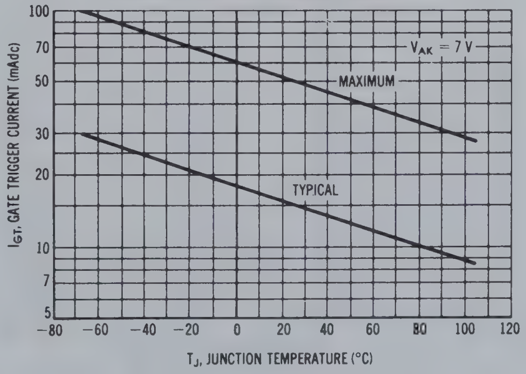


FIGURE 15 — TYPICAL BLOCKING VOLTAGE DERATING

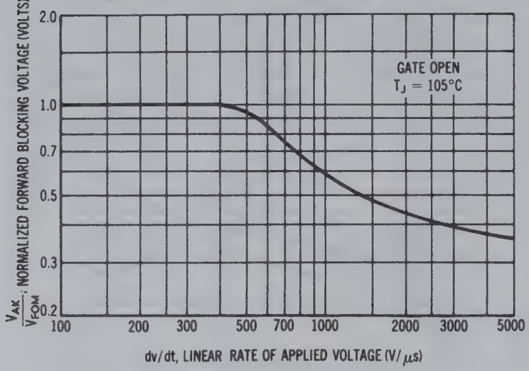


FIGURE 16 — TYPICAL dv/dt CAPABILITY

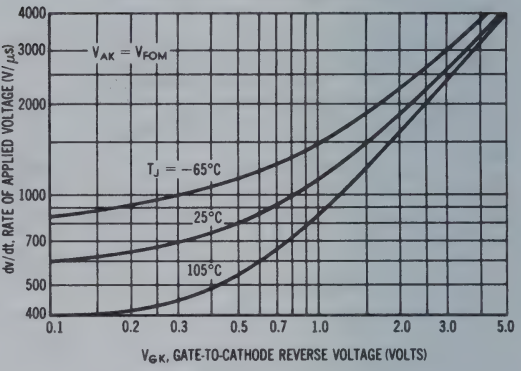


FIGURE 17 — FORWARD BLOCKING CURRENT

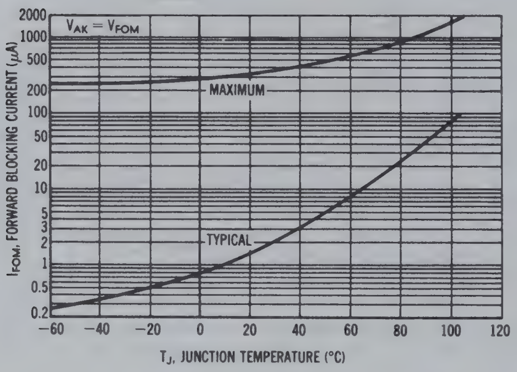


FIGURE 18 — HOLDING CURRENT

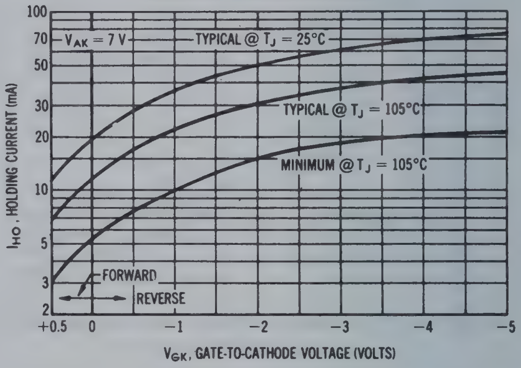


FIGURE 19 — TYPICAL ANODE-TO-CATHODE CAPACITANCE

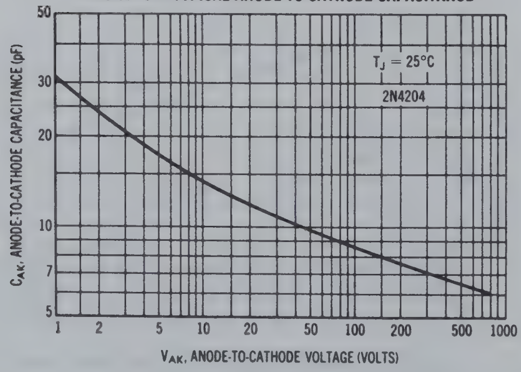
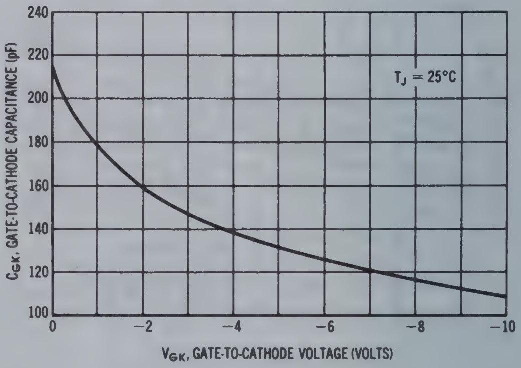


FIGURE 20 — TYPICAL GATE-TO-CATHODE CAPACITANCE



2N4212 thru 2N4216 (SILICON)

CASE 31(2)
(TO-5)

PNPN thyristors (silicon controlled rectifiers) designed for operation in mA/μA signal or detection circuits.

MAXIMUM RATINGS * (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1) 2N4212 2N4213 2N4214 2N4215 2N4216	$V_{RSM(rep)}$	 25 50 100 150 200	Volt
Forward Current RMS (All Conduction Angles)	I_T	1.6	Amp
Peak Surge Current (One Cycle, 60 Hz) No Repetition until Thermal Equilibrium is Restored	$I_{FM(surge)}$	15	Amp
Peak Gate Power - Forward	P_{GM}	0.1	Watt
Average Gate Power - Forward	$P_{G(AV)}$	0.01	Watt
Peak Gate Current - Forward	I_{GM}	0.1	Amp
Peak Gate Voltage - Forward Reverse	V_{GFM} V_{GRM}	6.0 6.0	Volt
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Lead Solder Temperature (> 1/16" from case, 10 sec. max)	-	+230	°C

* JEDEC Registered Values.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1)	V_{DRM}			Volt
2N4212		25*	-	
2N4213		50*	-	
2N4214		100*	-	
2N4215		150*	-	
2N4216		200*	-	
Peak Reverse Blocking Current (Rated V_{RSM}, T_J = 125°C)	I_{RRM}	-	200*	μA
Peak Forward Blocking Current (Rated V_{DRM}, T_J = 125°C)	I_{DRM}	-	200*	μA
Forward "On" Voltage	V_F			Volt
(I_F = 1.0 A Peak)		-	1.5	
(I_F = 3.14 A Peak)		-	2.0*	
Gate Trigger Current (Note 2) (Anode Voltage = 7.0 V, R_L = 100 ohms)	I_{GT}			μAdc
(T_C = 25°C)		-	100	
(T_C = -65°C)		-	300*	
Gate Trigger Voltage (Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = 25°C)	V_{GT}	-	0.8	Volt
(Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = -65°C)	V_{GT}	-	1.0*	
(Anode Voltage = Rated V_{DRM}, R_L = 100 ohms, T_J = 125°C)	V_{GNT}	0.1*	-	
Holding Current (Anode Voltage = 7.0 V) T_C = 25°C	I_{HX}		3.0	mA
T_C = -65°C			7.0*	
Turn-On Time	t_{gt}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_q			

* JEDEC Registered Values

Notes: 1. V_{RRM} and V_{DRM} can be applied for all types on a continuous dc basis without incurring damage.

2. R_{GK} current is not included in measurement.

Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 — CASE TEMPERATURE vs CURRENT

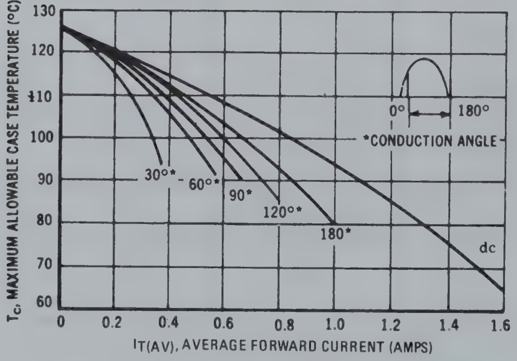
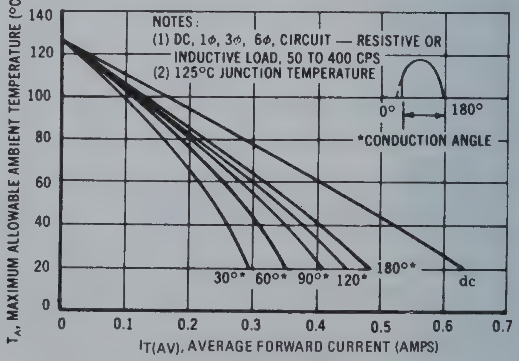


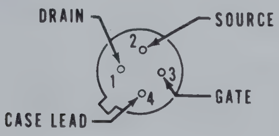
FIGURE 2 — AMBIENT TEMPERATURE vs CURRENT



2N4220 thru 2N4222 (SILICON)
2N4220A thru 2N4222A

N-channel junction silicon field-effect transistors designed for general purpose amplifier and switching applications. "A" types guarantee low noise figure (2.5 dB maximum @ 100 kHz).

CASE 20(3)
(TO-72)



Drain and Source
may be interchanged.

MAXIMUM RATINGS

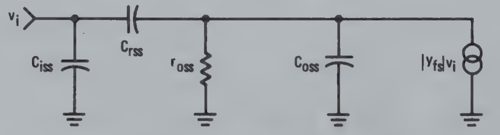
Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Drain Current	I_D	15	mAdc
Total Device Dissipation @ T_A = 25°C Derate Above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = -10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	-30	-	-	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)	I_{GSS}	-	-	-0.1	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 150°C)		-	-	-100	
Gate-Source Voltage (I_D = 50 μAdc, V_{DS} = 15 Vdc) 2N4220, 2N4220A	V_{GS}	-0.5	-	-2.5	Vdc
(I_D = 200 μAdc, V_{DS} = 15 Vdc) 2N4221, 2N4221A		-1.0	-	-5.0	
(I_D = 500 μAdc, V_{DS} = 15 Vdc) 2N4222, 2N4222A		-2.0	-	-6.0	
Gate-Source Cutoff Voltage (I_D = 0.1 nAdc, V_{DS} = 15 Vdc) 2N4220, 2N4220A	$V_{GS(off)}$	-	-	-4.0	Vdc
2N4221, 2N4221A		-	-	-6.0	
2N4222, 2N4222A		-	-	-8.0	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current (1) (V_{DS} = 15 Vdc, V_{GS} = 0) 2N4220, 2N4220A	I_{DSS}	0.5	-	3.0	mAdc
2N4221, 2N4221A		2.0	-	6.0	
2N4222, 2N4222A		5.0	-	15	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (1) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz) 2N4220, 2N4220A	$\|y_{fs}\|$	1000	2500	4000	μmhos
2N4221, 2N4221A		2000	3500	5000	
2N4222, 2N4222A		2500	4500	6000	
Output Admittance (1) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz) 2N4220, 2N4220A	$\|y_{os}\|$	-	-	10	μmhos
2N4221, 2N4221A		-	-	20	
2N4222, 2N4222A		-	-	40	
Drain-Source Resistance (V_{DS} = 0, V_{GS} = 0) 2N4220, 2N4220A	$r_{ds(on)}$	-	500	-	Ohms
2N4221, 2N4221A		-	400	-	
2N4222, 2N4222A		-	300	-	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	4.5	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	1.2	2.0	pF
Common-Source Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 30 MHz)	C_{osp}	-	1.5	-	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1.0 Megohm, f = 100 Hz) 2N4220A	NF	-	-	2.5	dB
2N4221A		-	-	2.5	
2N4222A		-	-	2.5	

(1) Pulse Test: Pulse Width = 630 ms, Duty Cycle = 10%

FIGURE 1 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
Y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega\, C_{iss}$
$y_{os} = j\omega\, C_{osp}^{*} + 1/r_{oss}$
$y_{fs} = |y_{fs}|$
$y_{rs} = -j\omega\, C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

FIGURE 2 – FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

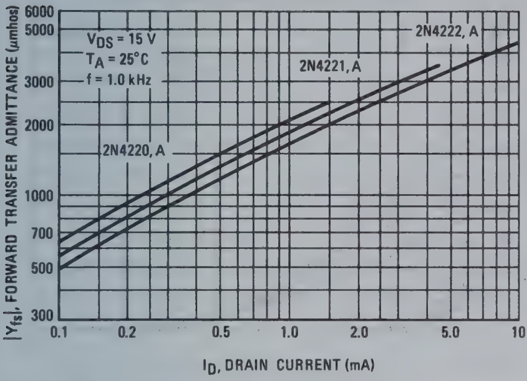


FIGURE 3 – TEMPERATURE COEFFICIENT OF Y_{fs} versus DRAIN CURRENT

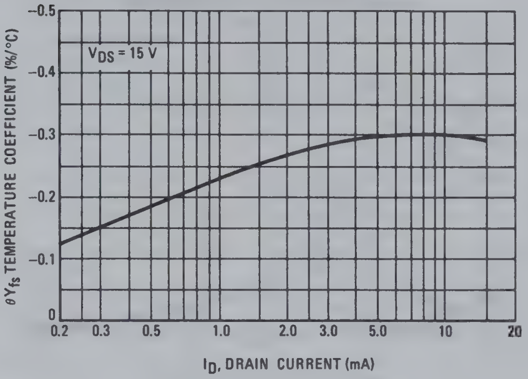


FIGURE 4 – OUTPUT RESISTANCE versus DRAIN CURRENT

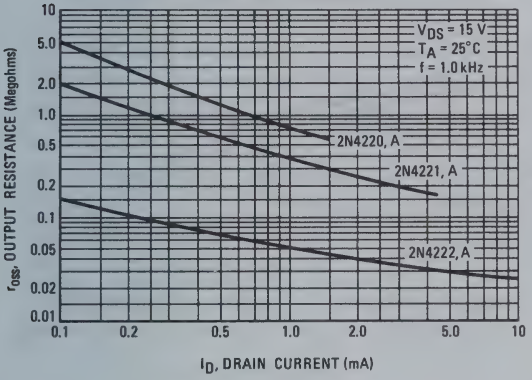


FIGURE 5 – CAPACITANCE versus DRAIN-SOURCE VOLTAGE

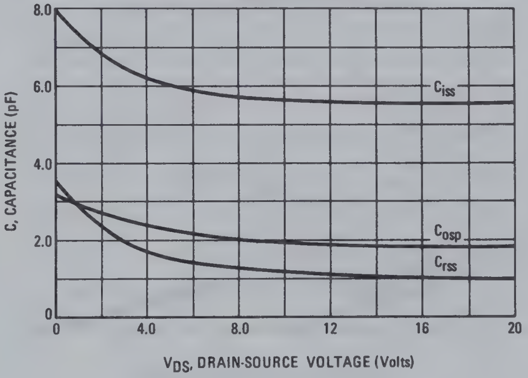


FIGURE 6 – NOISE FIGURE versus FREQUENCY

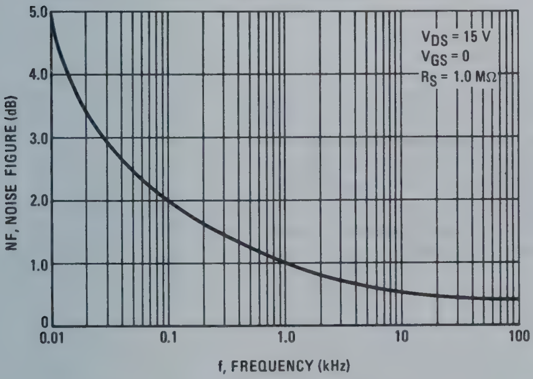


FIGURE 7 – NOISE FIGURE versus SOURCE RESISTANCE

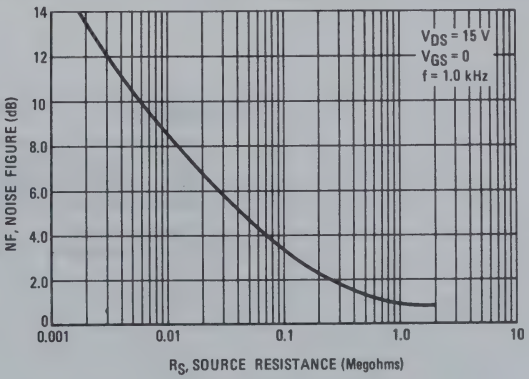


FIGURE 8 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

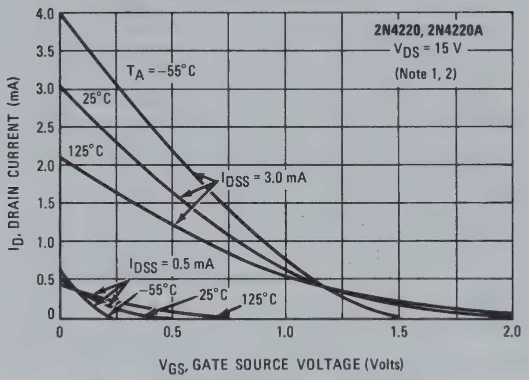


FIGURE 9 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

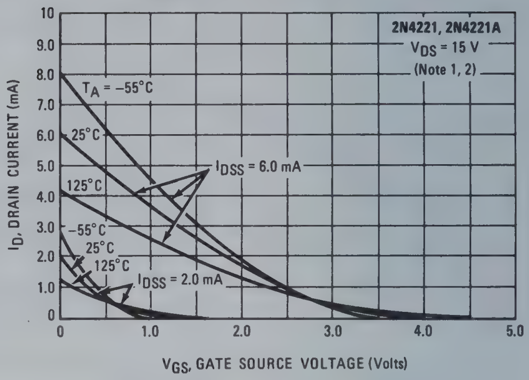


FIGURE 10 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

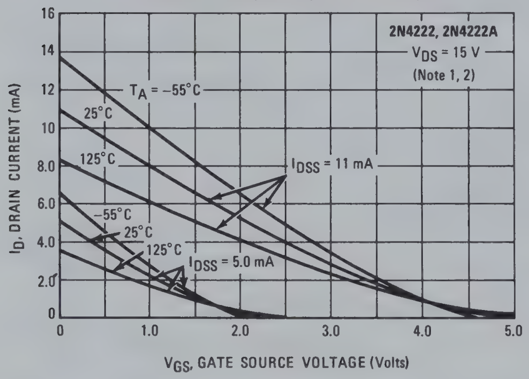
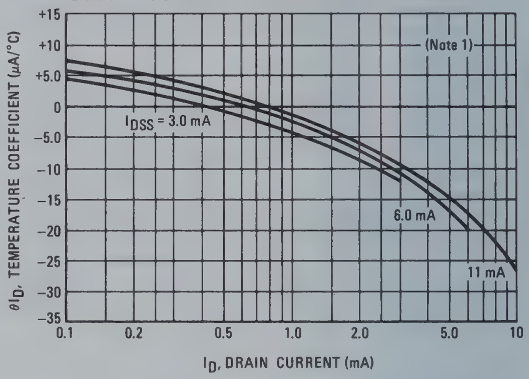


FIGURE 11 – TEMPERATURE COEFFICIENT OF DRAIN CURRENT versus DRAIN CURRENT



NOTES:

1. Graphical data is presented for dc conditions. Tabular data is given for pulsed conditions (Pulse Width = 630 ms, Duty Cycle = 10%). Under dc conditions, self heating in higher I_{DSS} units reduces I_{DSS} (See Figure 10).
2. Figures 8, 9, 10: Data taken in a standard printed circuit with a TO-18 type socket mounting and 1/4" lead length.

2N4223 (SILICON)
2N4224

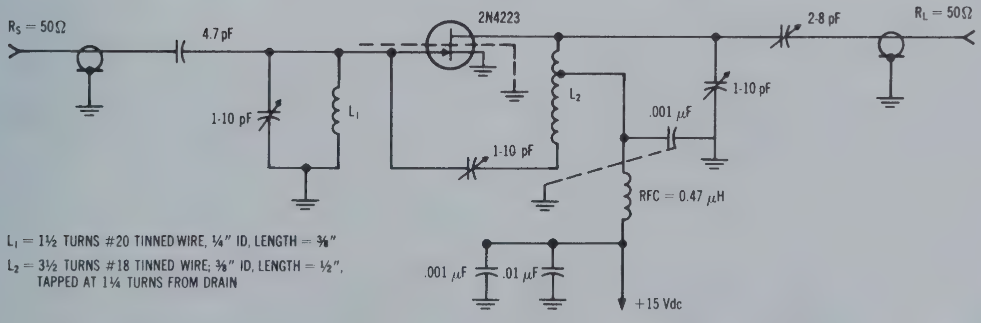
CASE 20(3)
(TO-72)

Silicon N-channel junction field-effect transistors, designed for VHF amplifier and mixer applications. Drain and Source interchangeable.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Drain Current	I_D	20	mAdc
Power Dissipation Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — NOISE FIGURE AND POWER GAIN TEST CIRCUIT


R_S = 50Ω
4.7 pF
2N4223
2-8 pF
R_L = 50Ω
1-10 pF
L_1
L_2
1-10 pF
.001 μF
1-10 pF
RFC = 0.47 μH
.001 μF
.01 μF
+15 Vdc

L_1 = 1½ TURNS #20 TINNED WIRE, ¼" ID, LENGTH = ⅜"
L_2 = 3½ TURNS #18 TINNED WIRE; ⅜" ID, LENGTH = ½",
TAPPED AT 1¼ TURNS FROM DRAIN

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	30	-	Vdc
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0)	2N4223 2N4224	I_{GSS}	- -	0.25 0.50	nAdc
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 100°C)	2N4223 2N4224		- -	250 500	
Gate-Source Cutoff Voltage (I_D = 0.25 nAdc, V_{DS} = 15 Vdc)	2N4223	$V_{GS(off)}$	-	8.0	Vdc
(I_D = 0.50 nAdc, V_{DS} = 15 Vdc)	2N4224		-	8.0	
Gate-Source Voltage (I_D = 0.3 mAdc, V_{DS} = 15 Vdc)	2N4223	V_{GS}	1.0	7.0	Vdc
(I_D = 0.2 mAdc, V_{DS} = 15 Vdc)	2N4224		1.0	7.5	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current (1) (V_{DS} = 15 Vdc, V_{GS} = 0)	2N4223 2N4224	I_{DSS}	3.0 2.0	18 20	mAdc
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz) (1)	2N4223 2N4224	$\|y_{fs}\|$	3000 2000	7000 7500	μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	2N4223 2N4224		2700 1700	- -	
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)		$Re(y_{is})$	-	800	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)		$Re(y_{os})$	-	200	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)		C_{iss}	-	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)		C_{rss}	-	2.0	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1 k ohm, f = 200 MHz)	2N4223	NF	-	5.0	dB
Small-Signal Power Gain (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	2N4223	G_{ps}	10	-	dB

(1) Pulse Test: Pulse Width ≦ 630 ms, Duty Cycle ≦ 10%

FIGURE 2 –
DRAIN CURRENT versus GATE-SOURCE VOLTAGE

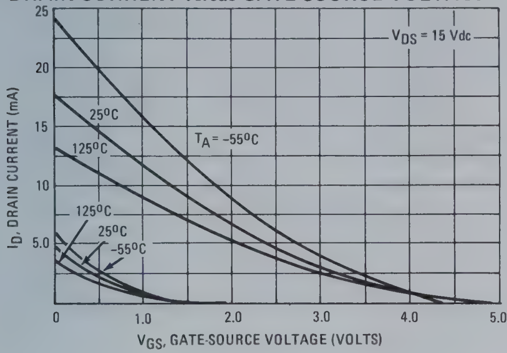


FIGURE 3 –
TEMPERATURE COEFFICIENT FOR DRAIN CURRENT

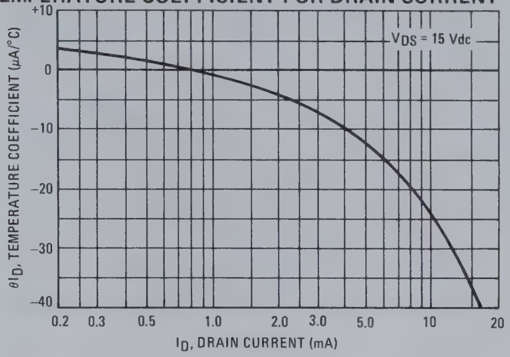


FIGURE 4 – FORWARD TRANSFER ADMITTANCE
versus GATE-SOURCE VOLTAGE

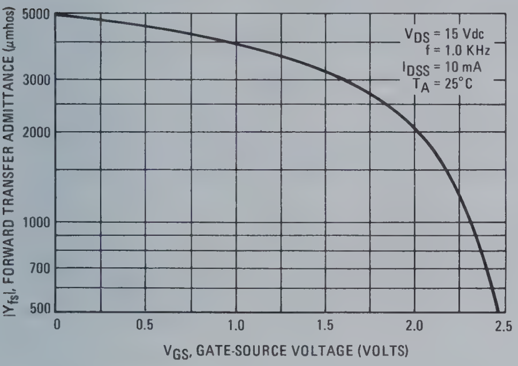


FIGURE 5 – TEMPERATURE COEFFICIENT FOR Y$_{fs}$
versus DRAIN CURRENT

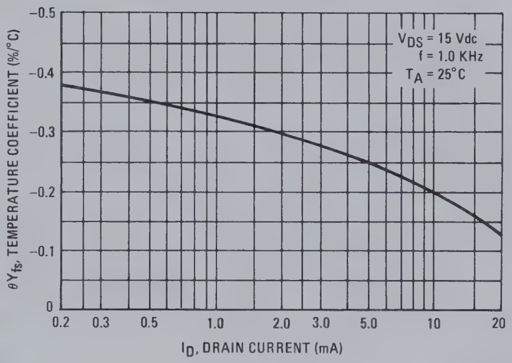


FIGURE 6 – CAPACITANCES

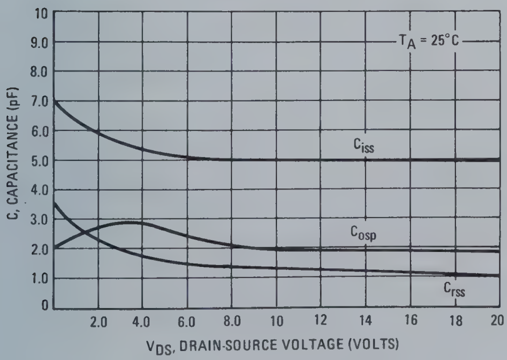


FIGURE 7 – COMMON SOURCE
NOISE FIGURE versus SOURCE RESISTANCE

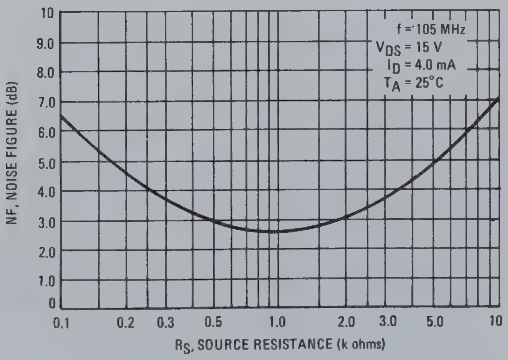


FIGURE 8 – INPUT ADMITTANCE versus FREQUENCY

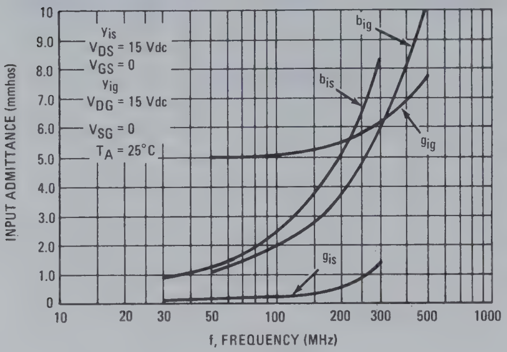


FIGURE 9 – FORWARD TRANSFER ADMITTANCE versus FREQUENCY

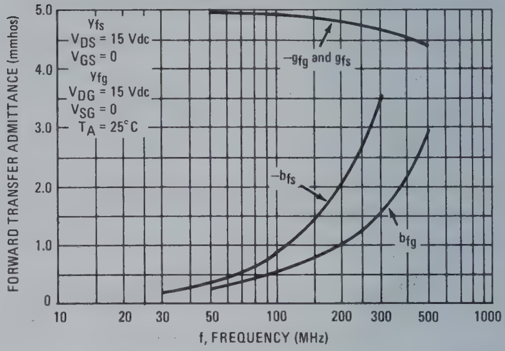


FIGURE 10 – OUTPUT ADMITTANCE versus FREQUENCY

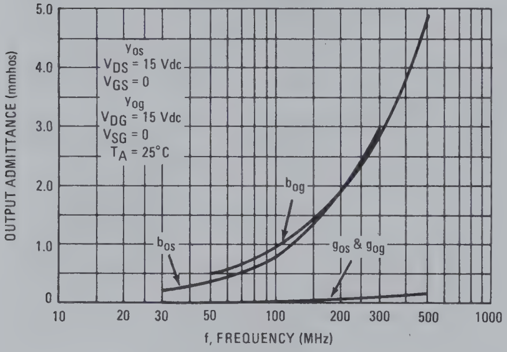


FIGURE 11 – REVERSE TRANSFER ADMITTANCE versus FREQUENCY

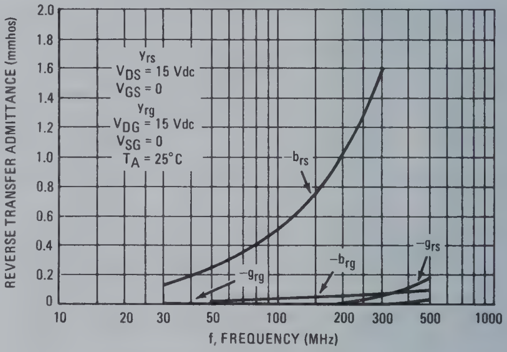


FIGURE 12 – POWER GAIN versus FREQUENCY

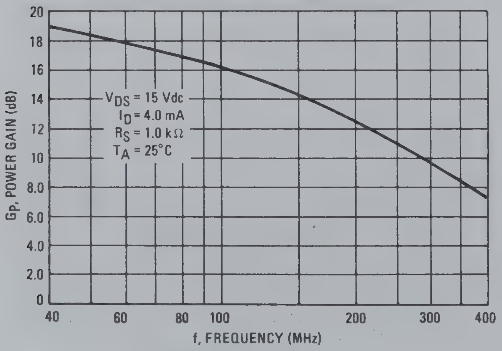
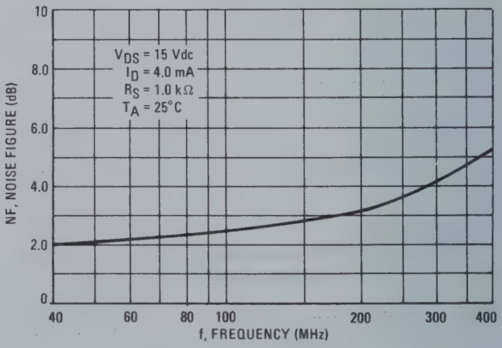


FIGURE 13 – COMMON SOURCE NOISE FIGURE versus FREQUENCY



2N4231 thru 2N4233 (SILICON)

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications.

CASE 80
(TO-66)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4231	2N4232	2N4233	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	50	70	90	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current - Continuous*	I_C*	3.0 5.0			Adc
Base Current	I_B	1.0			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	35 0.2			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	5.0	°C/W

* The 3.0 Amp maximum I_C value is based upon JEDEC current gain requirements.
The 5.0 Amp maximum value is based upon actual current-handling capability of the device.

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage[1] ($I_C = 100$ mAdc, $I_B = 0$)	2N4231 2N4232 2N4233	$BV_{CEO(sus)}$	40 60 80	- - -	Vdc
Collector Cutoff Current ($V_{CE} = 30$ Vdc, $I_B = 0$) ($V_{CE} = 50$ Vdc, $I_B = 0$) ($V_{CE} = 70$ Vdc, $I_B = 0$)	2N4231 2N4232 2N4233	I_{CEO}	- - -	1.0 1.0 1.0	mA
Collector Cutoff Current (V_{CE} @ rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc) (V_{CE} @ rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc, $T_C = 150°C$)		I_{CEX}	- -	0.1 1.0	mA
Collector Cutoff Current (V_{CB} @ rated V_{CB}, $I_E = 0$)		I_{CBO}	-	0.05	mA
Emitter Cutoff Current ($V_{BE} = 5.0$ V dc, $I_C = 0$)		I_{EBO}	-	500	uA
ON CHARACTERISTICS					
DC Current Gain[1] ($I_C = 0.5$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 1.5$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 3.0$ Adc, $V_{CE} = 2.0$ Vdc)		h_{FE}	40 25 10	- 100 -	-
Collector-Emitter Saturation Voltage[1] ($I_C = 1.5$ Adc, $I_B = 0.15$ Adc) ($I_C = 3.0$ Adc, $I_B = 0.3$ Adc)		$V_{CE(sat)}$	- -	0.7 2.0	Vdc
Base-Emitter Voltage[1] ($I_C = 1.5$ Adc, $V_{CE} = 2.0$ Vdc)		$V_{BE(on)}$	-	1.4	Vdc

[1] Pulse Test, PW ≈ 300 µs, Duty Cycle ≈ 2.0%

2N4231 thru 2N4233 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	4.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 kHz)	C_{ob}	-	200	pF
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	20	-	-

FIGURE 1 — NORMALIZED DC CURRENT GAIN

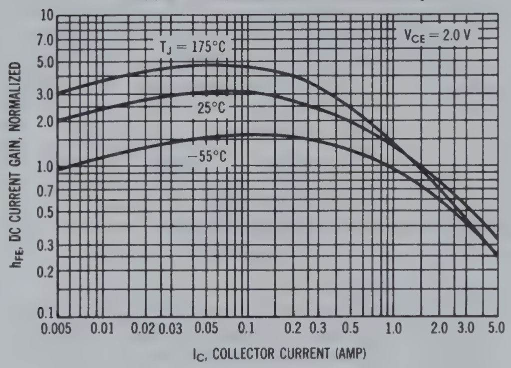


FIGURE 2 — COLLECTOR SATURATION REGION

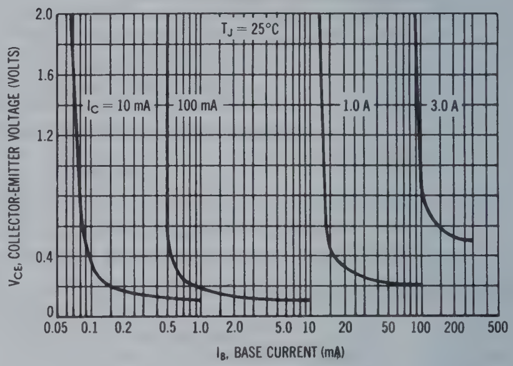


FIGURE 3 — "ON" VOLTAGES

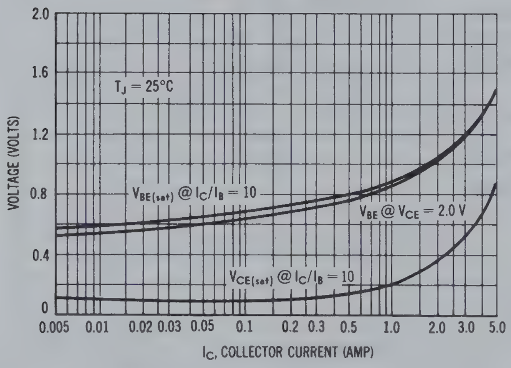


FIGURE 4 — TEMPERATURE COEFFICIENTS

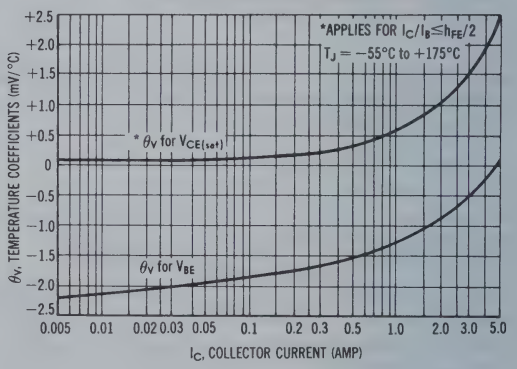


FIGURE 5 — SWITCHING TIME EQUIVALENT CIRCUIT

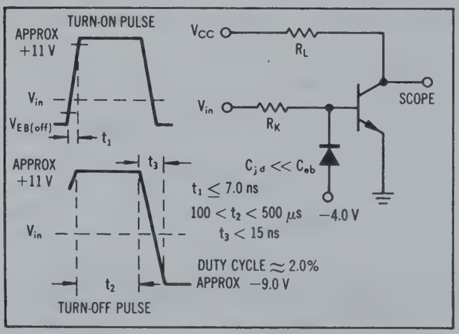
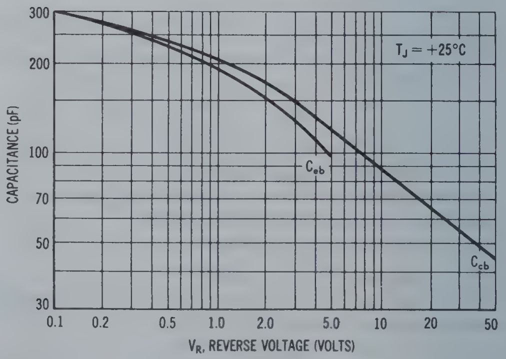

APPROX +11 V
TURN-ON PULSE
V_{in}
$V_{EB(off)}$
t_1
APPROX +11 V
t_3
V_{in}
t_2
TURN-OFF PULSE
V_{CC}
R_L
SCOPE
V_{in}
R_K
$C_{jd} << C_{eb}$
$t_1 \leq$ 7.0 ns
100 < t_2 < 500 μs
t_3 < 15 ns
−4.0 V
DUTY CYCLE ≈ 2.0%
APPROX −9.0 V

FIGURE 6 — CAPACITANCE



2N4231 thru 2N4233 (continued)

FIGURE 7 —TURN-ON TIME

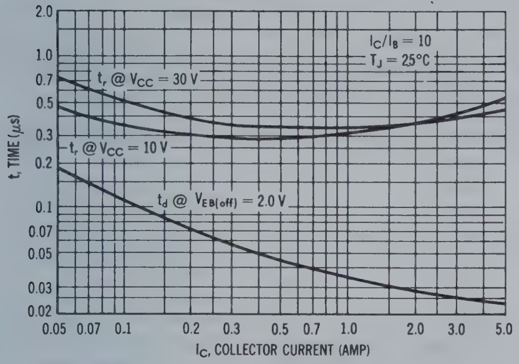
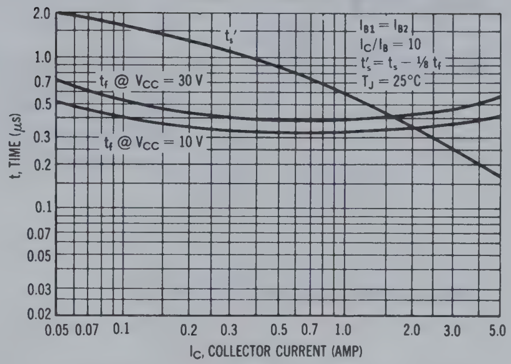


FIGURE 8 — TURN-OFF TIME



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 9 — CUT-OFF REGION

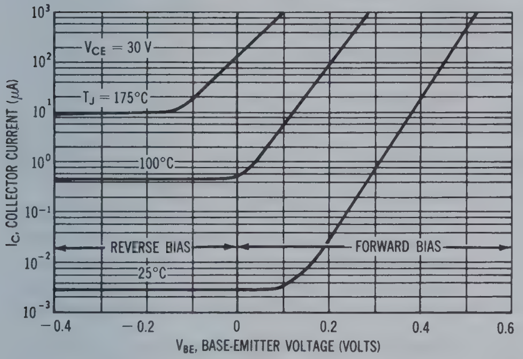


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

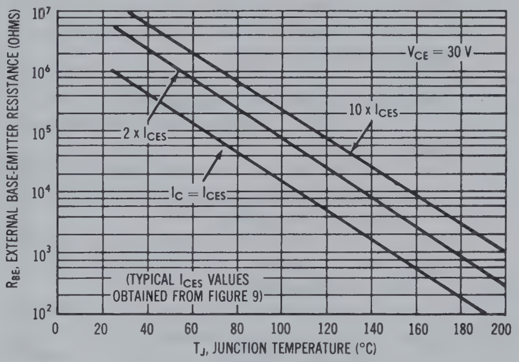
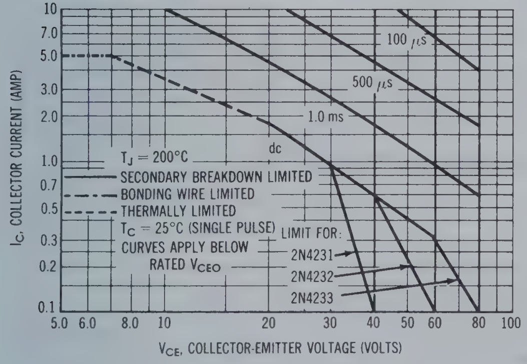


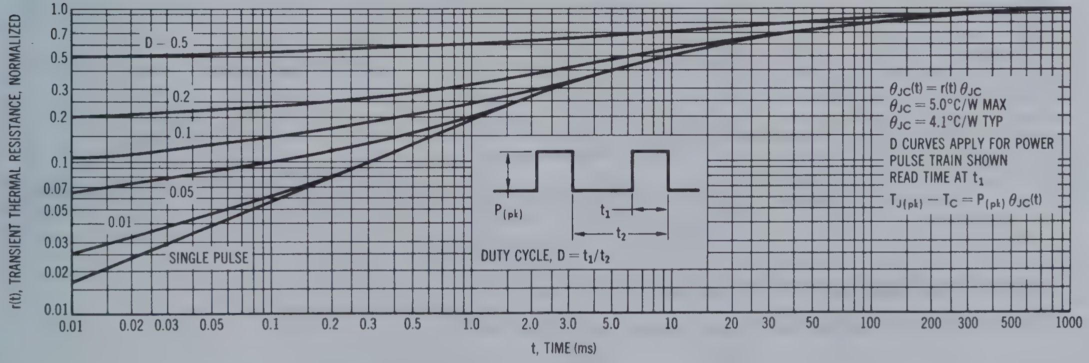
FIGURE 11 — ACTIVE-REGION SAFE-OPERATING AREA



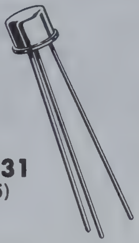
There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — THERMAL RESPONSE



2N4234 (SILICON)
2N4235
2N4236



CASE 31
(TO-5)

Collector connected to case

PNP silicon power transistors ideal for use as drivers, switches, and direct replacement of germanium medium-power devices. Complement to NPN 2N4237 thru 2N4239.

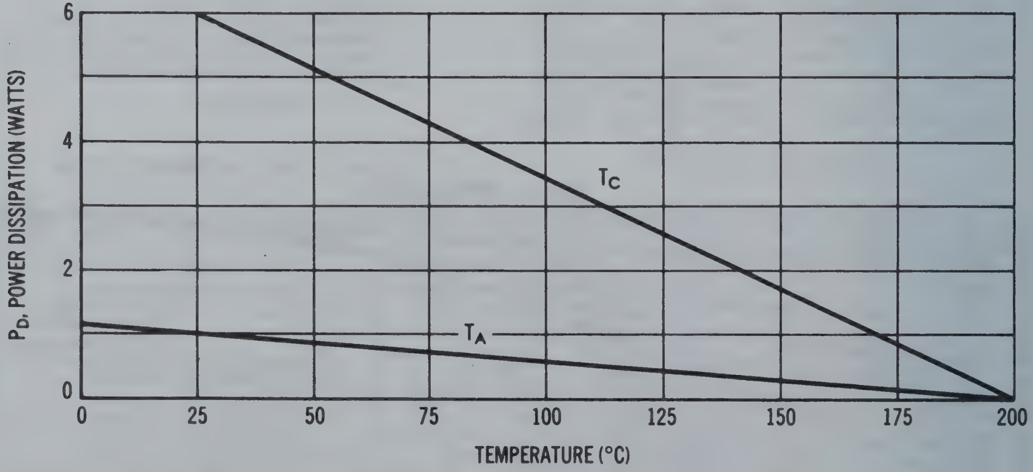
MAXIMUM RATINGS

Rating	Symbol	2N4234	2N4235	2N4236	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 7.0 →			Vdc
Collector Current — Continuous	I_C	← 3.0 →			Adc
Base Current	I_B	← 0.2 →			Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	← 1.0 → ← 5.7 →			Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 6.0 → ← 34 →			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θJC	29	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 2.

All limits are applicable and must be observed.

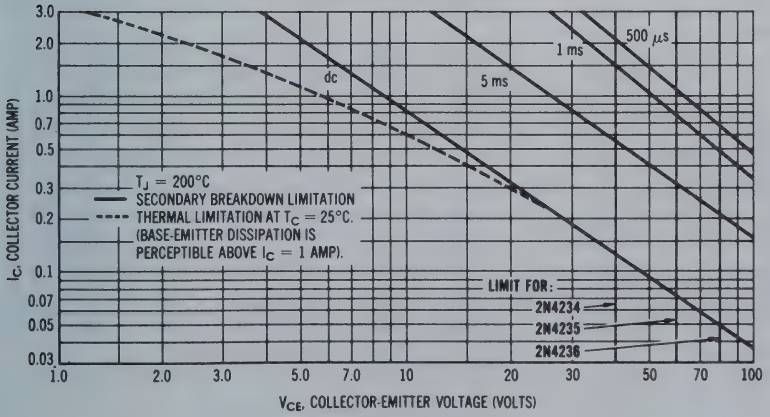
2N4234, 2N4235, 2N4236 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 100 mAdc, I_B = 0)	2N4234 2N4235 2N4236	$BV_{CEO(sus)}$	40 60 80	— — —	Vdc
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 30 Vdc, I_B = 0)	2N4234		—	1.0	
(V_{CE} = 40 Vdc, I_B = 0)	2N4235		—	1.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N4236		—	1.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4234		—	0.1	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4235		—	0.1	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4236		—	0.1	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4234		—	1.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4235		—	1.0	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4236		—	1.0	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N4234		—	0.1	
(V_{CB} = 60 Vdc, I_E = 0)	2N4235		—	0.1	
(V_{CB} = 80 Vdc, I_E = 0)	2N4236		—	0.1	
Emitter Cutoff Current (V_{BE} = 7 Vdc, I_C = 0)		I_{EBO}	—	0.5	mAdc
ON CHARACTERISTICS					
DC Current Gain (1)		h_{FE}			—
(I_C = 100 mAdc, V_{CE} = 1 Vdc)			40	—	
(I_C = 250 mAdc, V_{CE} = 1 Vdc)			30	150	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)			20	—	
(I_C = 1.0 Adc, V_{CE} = 1 Vdc)			10	—	
Collector-Emitter Saturation Voltage (1) (I_C = 1.0 Adc, I_B = 125 mAdc)		$V_{CE(sat)}$	—	0.6	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 1.0 Adc, I_B = 100 mAdc)		$V_{BE(sat)}$	—	1.5	Vdc
Base-Emitter On Voltage (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)		$V_{BE(on)}$	—	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)		f_T	3.0	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	100	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	25	—	—

(1) Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

FIGURE 2 — ACTIVE-REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE

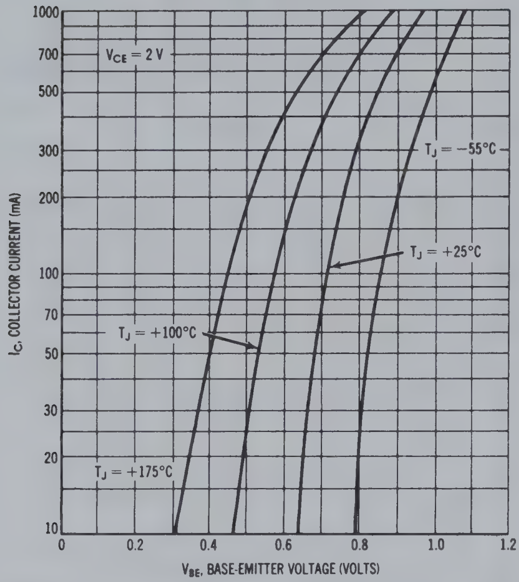
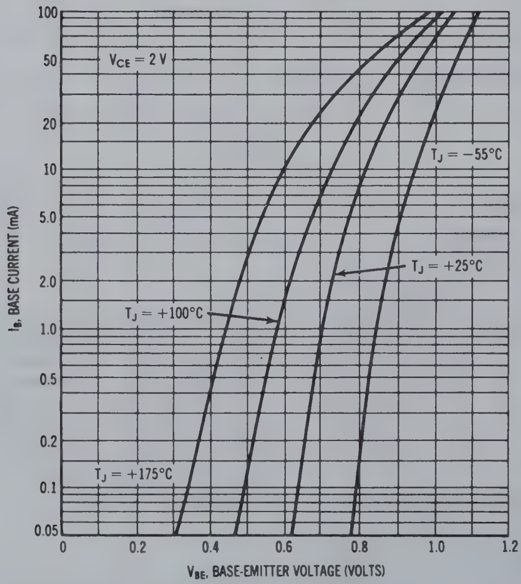


FIGURE 4 — INPUT ADMITTANCE



"OFF" REGION CHARACTERISTICS

FIGURE 5 — TRANSCONDUCTANCE

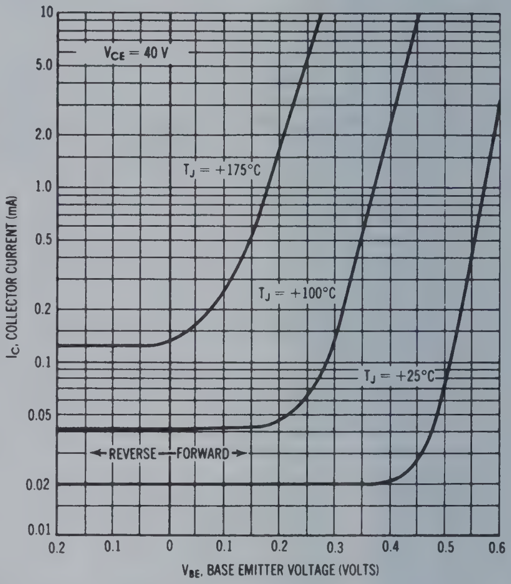


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

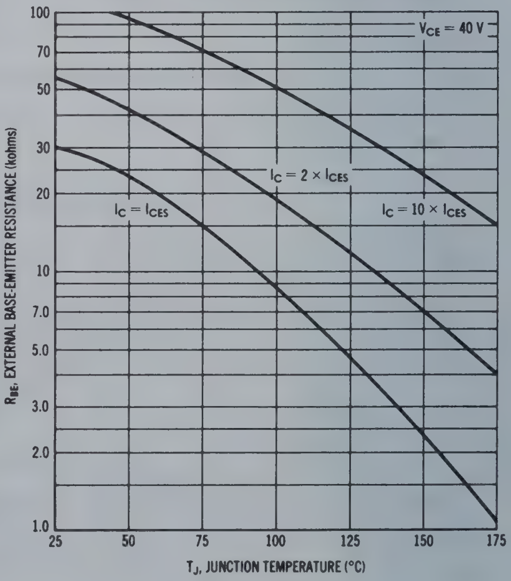
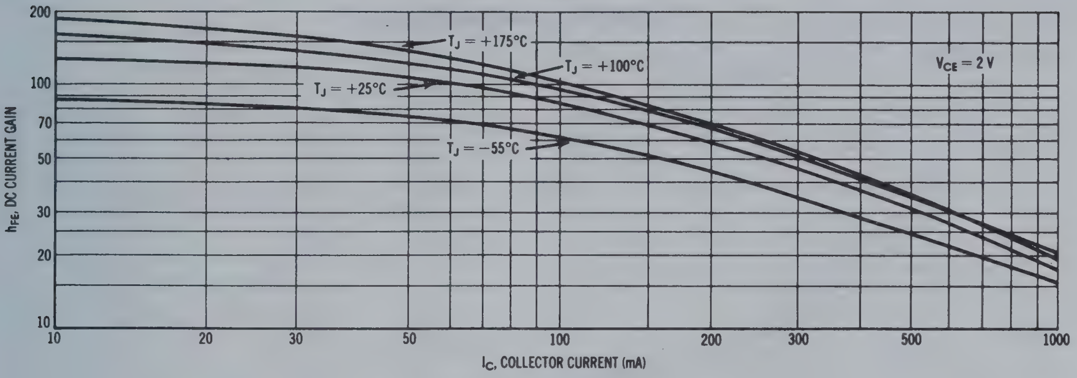


FIGURE 7 — CURRENT GAIN



SATURATION REGION CHARACTERISTICS

FIGURE 8 — COLLECTOR SATURATION REGION

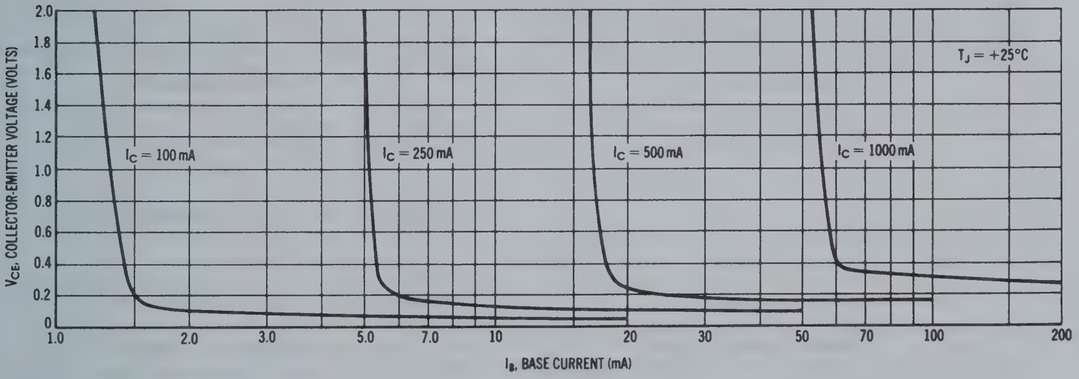


FIGURE 9 — "ON" VOLTAGES

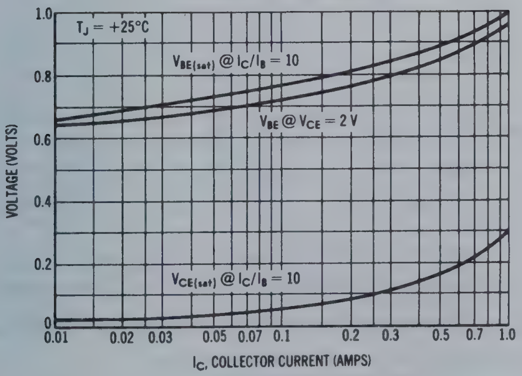
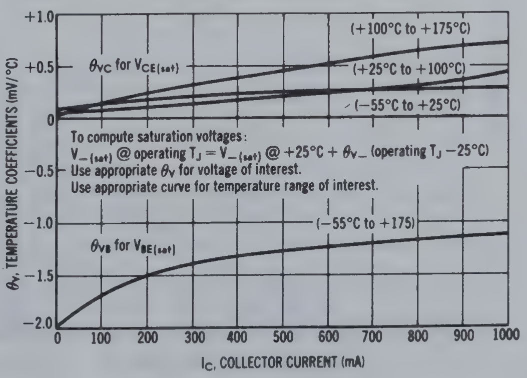


FIGURE 10 — TEMPERATURE COEFFICIENTS



To compute saturation voltages:
$V_{-(sat)}$ @ operating $T_J = V_{-(sat)}$ @ $+25°C + \theta_{V-}$ (operating $T_J - 25°C$)
Use appropriate θ_V for voltage of interest.
Use appropriate curve for temperature range of interest.

DYNAMIC CHARACTERISTICS

FIGURE 11 — TURN-ON TIME

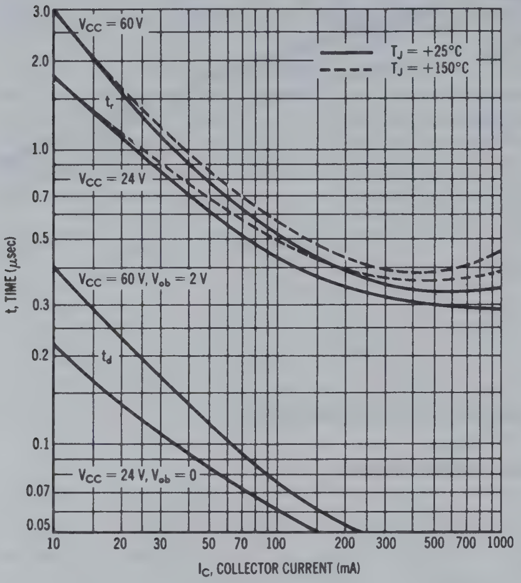


FIGURE 13 — CAPACITANCE

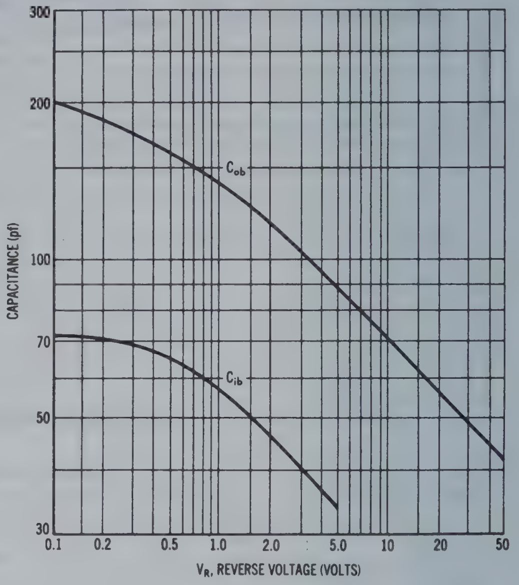


FIGURE 12 — STORAGE TIME

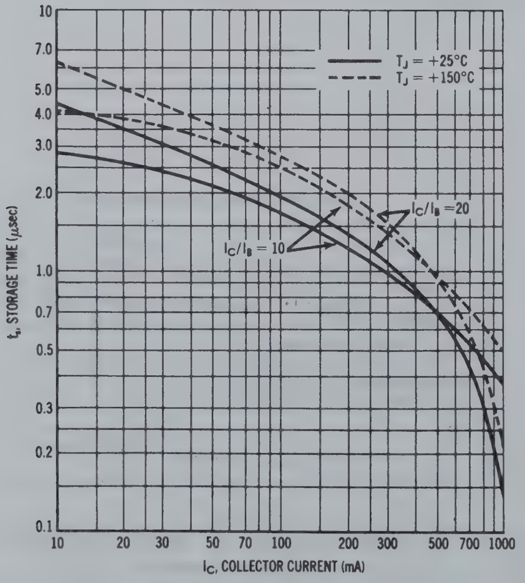
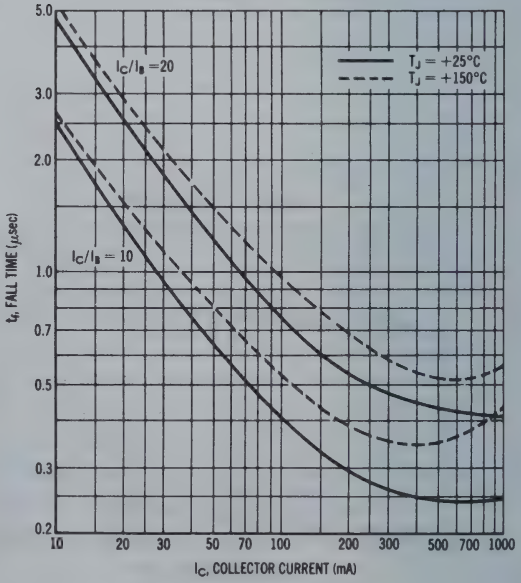


FIGURE 14 — FALL TIME



2N4237 (SILICON)
thru
2N4239

CASE 31
(TO-5)

Collector connected to case

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications.

MAXIMUM RATINGS

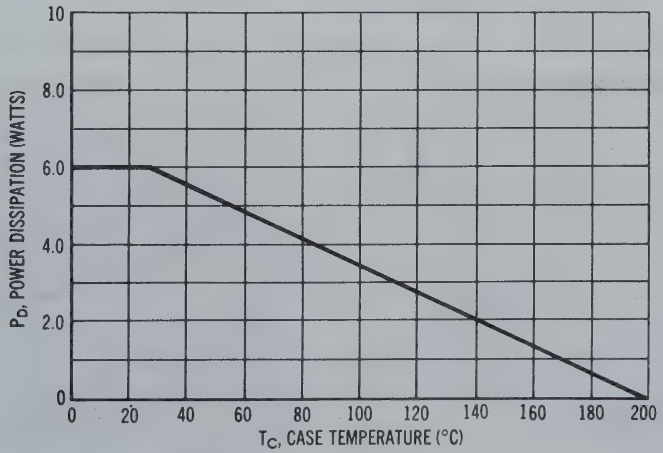
Rating	Symbol	2N4237	2N4238	2N4239	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	50	80	100	Vdc
Emitter-Base Voltage	V_{EB}	← 6.0 →			Vdc
Collector Current — Continuous*	I_C	← 1.0 → ← 3.0 →			Adc
Base Current — Continuous	I_B	← 500 →			mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 6.0 → ← 34 →			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	29	°C/W

*The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 3.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 100 mAdc, I_B = 0)	-	$BV_{CEO(sus)}$			Vdc
2N4237			40	-	
2N4238			60	-	
2N4239			80	-	
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, I_B = 0)	-	I_{CEO}	-	0.7	mAdc
Collector Cutoff Current	12	I_{CEX}			mAdc
(V_{CE} = 45 Vdc, $V_{EB(off)}$ = 1.5 Vdc)			-	0.1	
(V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc)			-	0.1	
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc)			-	0.1	
(V_{CE} = 30 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)			-	1.0	
(V_{CE} = 50 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)			-	1.0	
(V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)			-	1.0	
Collector Cutoff Current (V_{CB} = Rated V_{CBO}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)	-	I_{EBO}	-	0.5	mAdc
ON CHARACTERISTICS					
DC Current Gain (1)	8	h_{FE}			-
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			30	-	
(I_C = 250 mAdc, V_{CE} = 1.0 Vdc)			30	150	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)			30	-	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)			15	-	
Collector-Emitter Saturation Voltage (1)	9, 11, 13	$V_{CE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			-	0.3	
(I_C = 1.0 Adc, I_B = 0.1 Adc)			-	0.6	
Base-Emitter Saturation Voltage (1) (I_C = 1.0 Adc, I_B = 0.1 Adc)		$V_{BE(sat)}$	-	1.5	Vdc
Base-Emitter On Voltage (1) (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)	11, 13	$V_{BE(on)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	2.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	30	-	-

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

SWITCHING CHARACTERISTICS

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

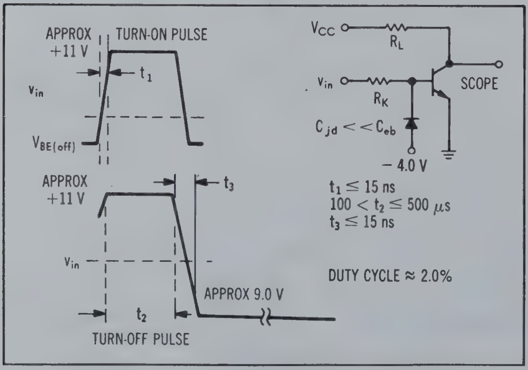

APPROX +11 V
TURN-ON PULSE
t_1
V_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
V_{in}
APPROX 9.0 V
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
− 4.0 V
$t_1 \leq 15$ ns
$100 < t_2 \leq 500$ μs
$t_3 \leq 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

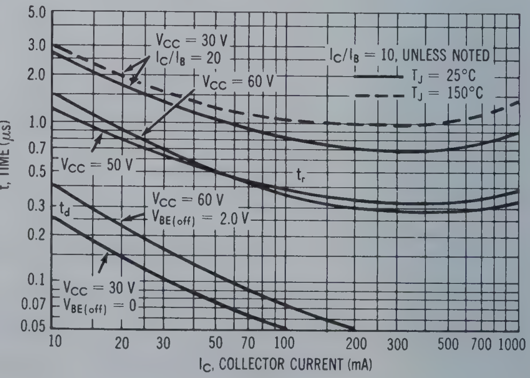


FIGURE 4 — THERMAL RESPONSE

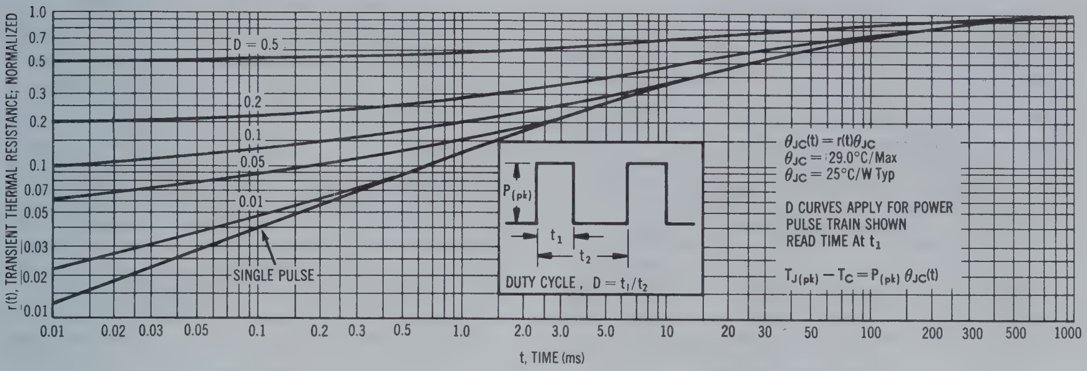
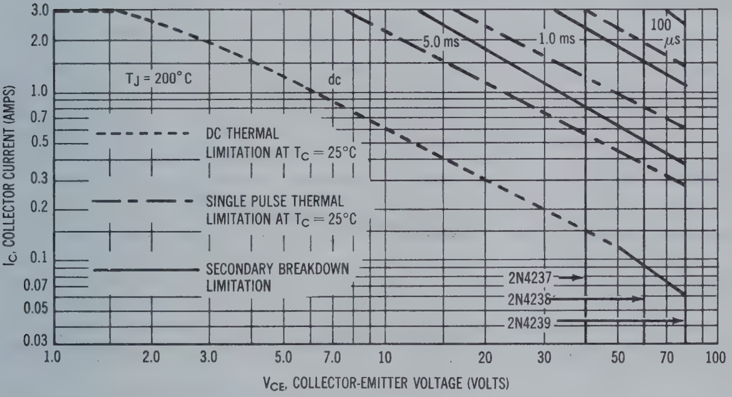


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

For this particular transistor family, the thermal curves are the limiting design values, except for a small portion of the dc curve. The pulse secondary breakdown curves are shown for information only.

FIGURE 6 — STORAGE TIME

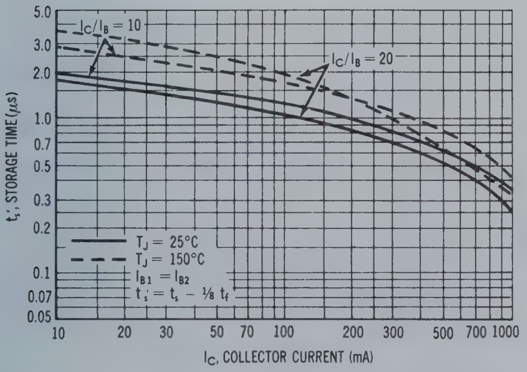
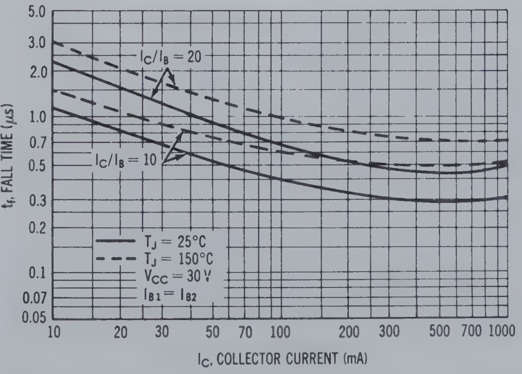


FIGURE 7 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 8 — CURRENT GAIN

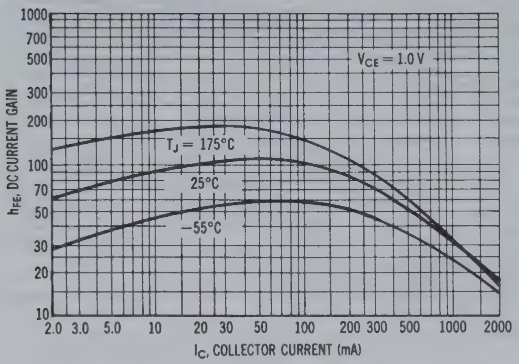


FIGURE 9 — COLLECTOR SATURATION REGION

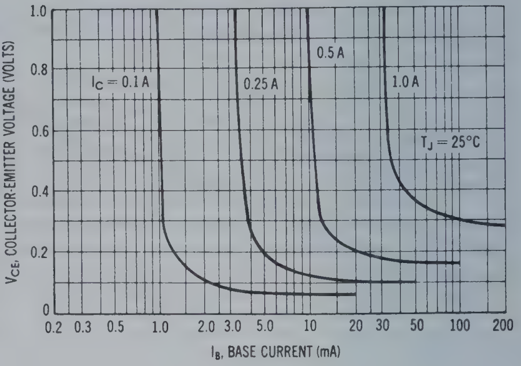


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

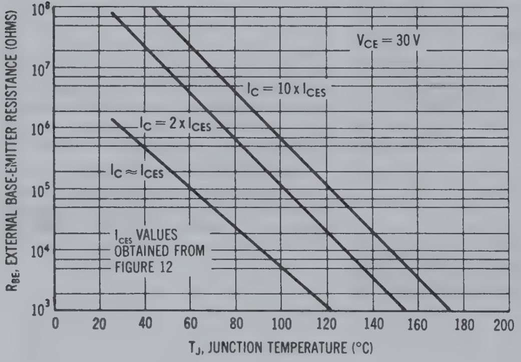


FIGURE 11 — "ON" VOLTAGE

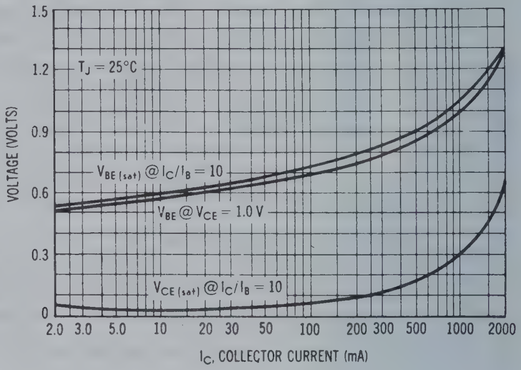


FIGURE 12 — COLLECTOR CUTOFF REGION

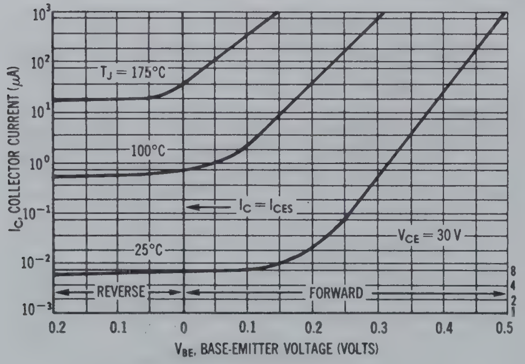
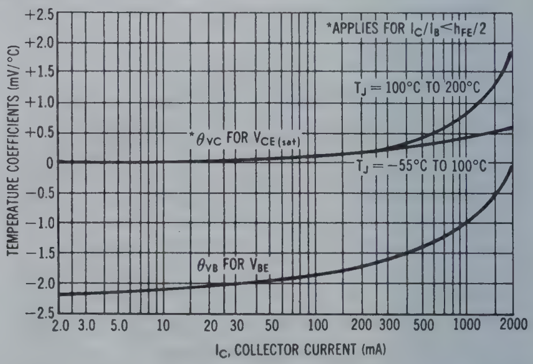


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4260 (SILICON)
2N4261

CASE 20
(TO-72)

PNP silicon annular transistors, designed for high-speed current-mode logic switching applications and for complementary circuitry with NPN types 2N3959 and 2N3960.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current - Continuous	I_C	30	mAdc
Total Device Dissipation @ T_A = 25°C	P_D	200	mW
Derate above 25°C		1.14	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_E = 0)		BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc)		I_{CEX}	-	0.005	μAdc
(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc, T_A = 150°C)			-	5.0	
(V_{CE} = 10 Vdc, $V_{EB(on)}$ = 0.4 Vdc)			-	0.05	
Base Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc)		I_{BL}	-	0.005	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc)	1	h_{FE}	25	-	-
(I_C = 10 mAdc, V_{CE} = 1 Vdc)			30	150	
(I_C = 30 mAdc, V_{CE} = 2 Vdc)			20	-	
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 Adc)	2, 3, 4	$V_{CE(sat)}$	-	0.15	Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			-	0.35	
Base-Emitter On Voltage (I_C = 1 mAdc, V_{CE} = 1 Vdc)	3, 4	$V_{BE(on)}$	-	0.8	Vdc
(I_C = 10 mAdc, V_{CE} = 1 Vdc)			-	1.0	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 100 MHz) 2N4260	5	f_T	1200	-	MHz
2N4261			1500	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4260			1600	-	
2N4261			2000	-	
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4260		$\lvert h_{fe} \rvert$	16	-	-
2N4261			20	-	
Output Capacitance (V_{CB} = 4 Vdc, I_E = 0, f = 100 kHz)	8	C_{ob}	-	2.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	8	C_{ib}	-	2.5	pF
Collector-Base Time Constant (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 31.8 MHz) 2N4260	6	$r_b'C_c$	-	35	ps
2N4261			-	60	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 31.8 MHz) 2N4260			-	30	
2N4261			-	50	

TYPICAL SWITCHING TIMES

			Typical Performance (v_{out} = 1 V)		
			@ 10 mA	@ 30 mA	
Turn-On Delay Time	Test Circuit Figure 7	$t_{on(delay)}$	1.0	1.2	ns
Rise Time		t_r	0.5	0.9	ns
Turn-Off Delay Time	Test Circuit Figure 7	$t_{off(delay)}$	1.0	1.2	ns
Fall-Time		t_f	1.0	1.2	ns

FIGURE 1 — DC CURRENT GAIN

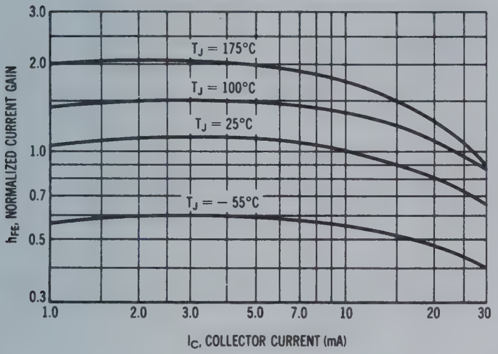
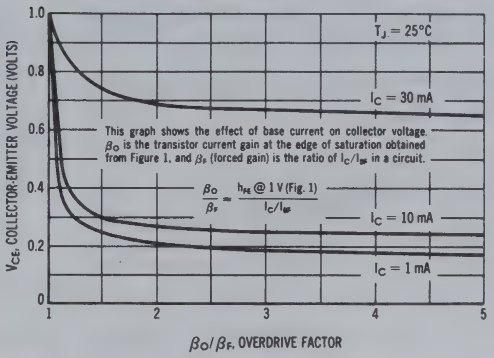


FIGURE 2 — COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector voltage. β_O is the transistor current gain at the edge of saturation obtained from Figure 1, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\ \text{V (Fig. 1)}}{I_C/I_{BF}}$$

FIGURE 3 — "ON" VOLTAGES

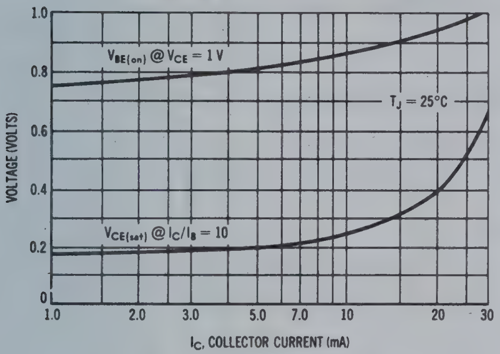


FIGURE 4 — TEMPERATURE COEFFICIENTS

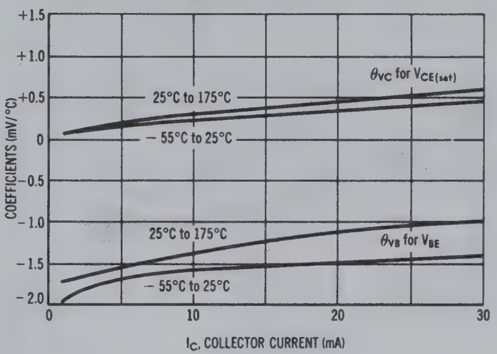


FIGURE 5 — CURRENT-GAIN — BANDWIDTH PRODUCT

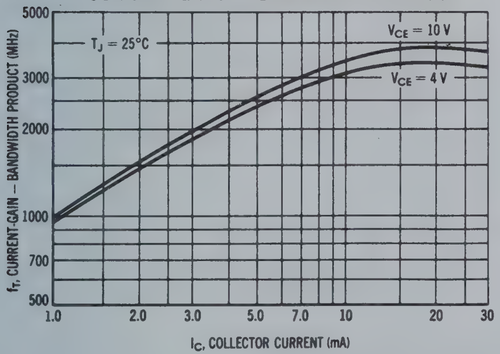


FIGURE 6 — COLLECTOR-BASE TIME CONSTANT

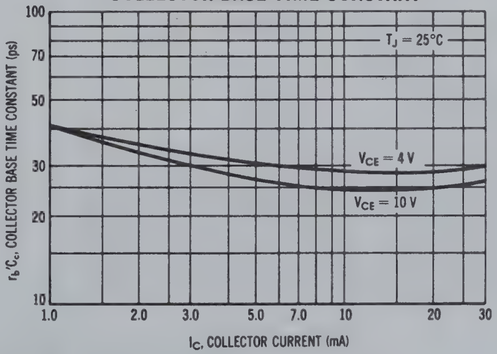
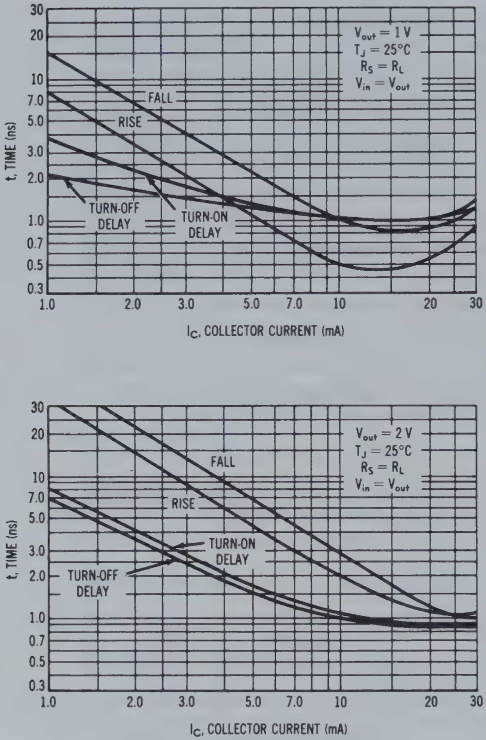
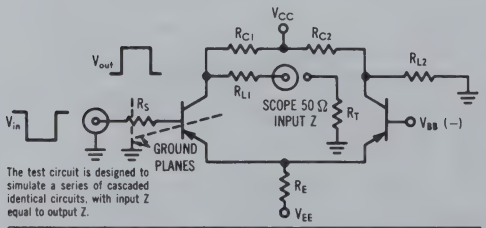


FIGURE 7 — SWITCHING TIMES




V_{CC}
R_{C1}
R_{C2}
V_{out}
R_{L1}
R_{L2}
V_{in}
R_S
SCOPE 50 Ω
INPUT Z
R_T
V_{BB} (−)
GROUND PLANES
R_E
V_{EE}

The test circuit is designed to simulate a series of cascaded identical circuits, with input Z equal to output Z.

	$V_{in} = V_{out} = 2$ V $V_{BB} = 1$ V $R_{C1} = R_{C2}$							$V_{in} = V_{out} = 1$ V $V_{BB} = 0.5$ V $R_{C1} = R_{C2}$						
I_C mA	R_S ohms	R_C ohms	R_{L1} ohms	R_{L2} ohms	R_E ohms	V_{EE} volts	V_{CC} volts	R_S ohms	R_C ohms	R_{L1} ohms	R_{L2} ohms	R_E ohms	V_{EE} volts	V_{CC} volts
1	2 k	6 k	3 k	3 k	10 k	10	16	1 k	6 k	1.2 k	1.2 k	24 k	24	32
5	360	3.56 k	400	450	2 k	10	47	175	1 k	200	250	3 k	15	27
10	160	1 k	200	250	3 k	30	26.3	75	300	100	150	3 k	30	17
20	62	300	100	150	1 k	20	16	25	150	25	75	1 k	20	11
30	28	157	66	116	1 k	30	13	8	77	0	50	1 k	30	9

FIGURE 8 — CAPACITANCE

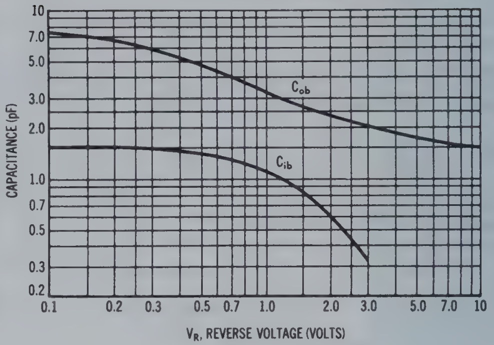
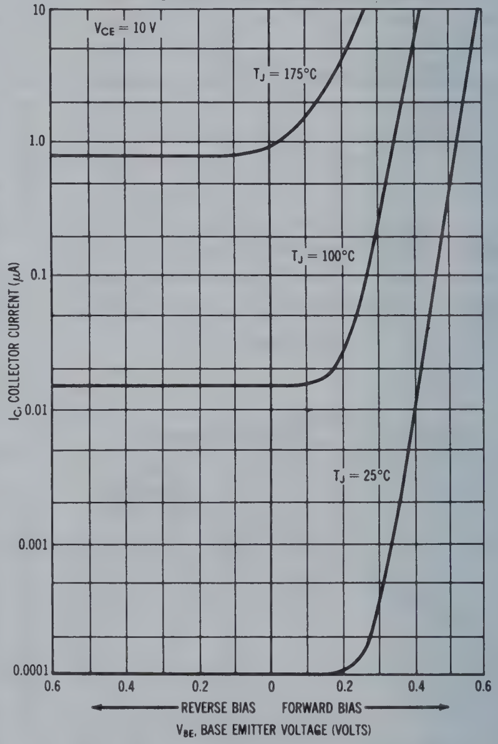
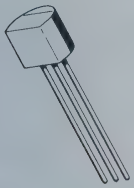


FIGURE 9 — CUT-OFF CHARACTERISTICS



2N4264 (SILICON)

2N4265



CASE 29(1)
(TO-92)

NPN silicon annular transistors, designed for low-level, saturated logic applications featuring one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

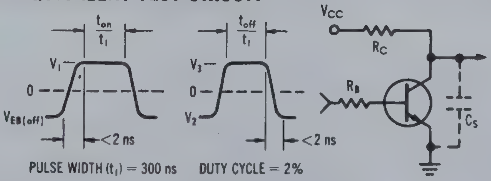
Rating	Symbol	2N4264	2N4265	Unit
Collector-Emitter Voltage	V_{CEO}	15	12	Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	350 2.73		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — SWITCHING TIME EQUIVALENT TEST CIRCUIT

TEST CONDITION	I_C	V_{CC}	R_B	R_C	$C_{S(max)}$	$V_{EB(off)}$	V_1	V_2	V_3
	mA	V	Ω	Ω	pF	V	V	V	V
A	10	3	3300	270	4	−1.5	10.55	−4.15	10.70
B	10	10	560	960	4	—	—	−4.65	6.55
C	100	10	560	96	12	−2.0	6.35	−4.65	6.55



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_E = 0) 2N4264 2N4265		BV_{CEO}	15 12	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc)		I_{CEX}	—	100	nAdc
Base Cutoff Current (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc) (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 100°C)		I_{BL}	— —	0.1 10	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265	2	h_{FE}	25 50	— —	—
(I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265			40 100	160 400	
(I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C) 2N4264 2N4265			20 45	— —	
(I_C = 30 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265			40 90	— —	
(I_C = 100 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265			30 55	— —	
(I_C = 200 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265			20 35	— —	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	5, 6, 7	$V_{CE(sat)}$	— —	0.22 0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	6, 7	$V_{BE(sat)}$	0.65 0.75	0.80 0.95	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	300	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)	12	C_{ob}	—	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	12	C_{ib}	—	8.0	pF

SWITCHING CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Turn-On Time	Figure 1, Test Condition A V_{CC} = 3 Vdc, $V_{EB(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3 mAdc	1	t_{on}	—	25	ns
Turn-Off Time	Figure 1, Test Condition A V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1.5 mAdc	1	t_{off}	—	35	ns
Storage Time	Figure 1, Test Condition B V_{CC} = 10 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc	1	t_s	—	20	ns
Delay Time	Figure 1, Test Condition C V_{CC} = 10 Vdc, $V_{EB(off)}$ = 2 Vdc, I_C = 100 mAdc, I_{B1} = 10 mAdc	1, 8	t_d	—	8.0	ns
Rise Time		1, 9	t_r	—	15	ns
Storage Time	Figure 1, Test Condition C V_{CC} = 10 Vdc, I_C = 100 mAdc, I_{B1} = I_{B2} = 10 mAdc	1, 10	t_s	—	20	ns
Fall Time		1, 11	t_f	—	15	ns
Total Control Charge	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_B = mAdc	3, 13	Q_T	—	80	pC

CURRENT GAIN CHARACTERISTICS

FIGURE 2 — MINIMUM CURRENT GAIN

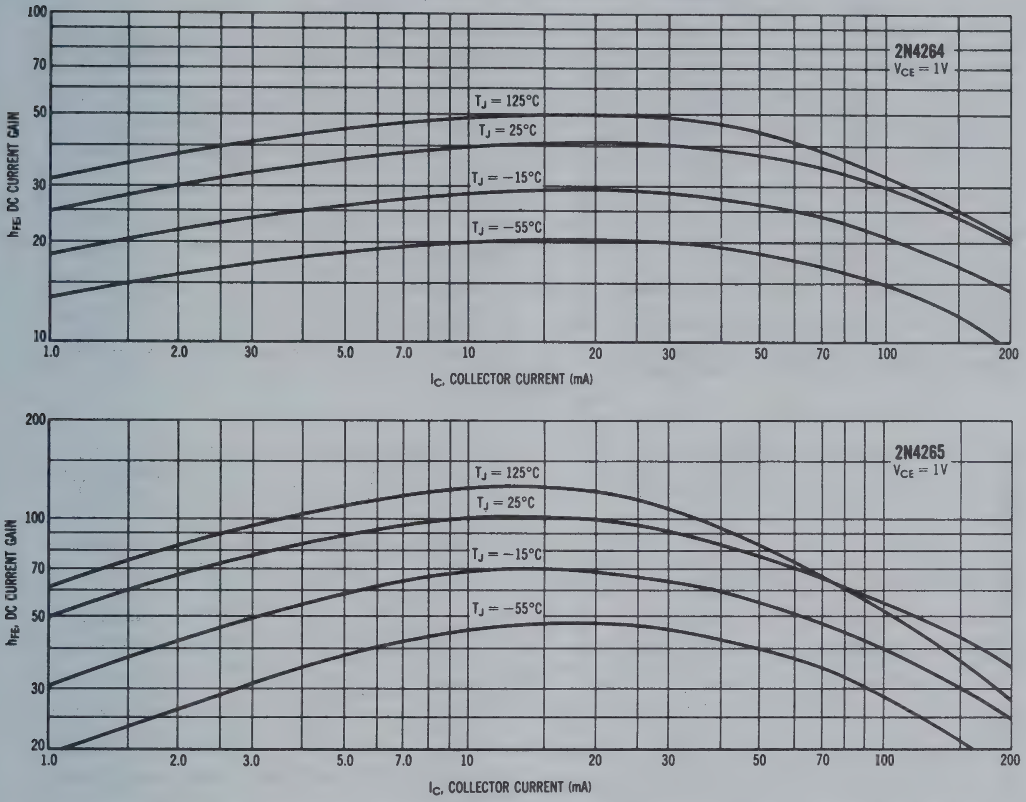
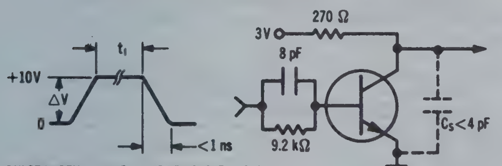
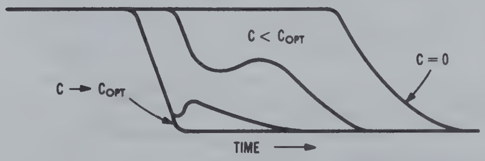


FIGURE 3 — Q_T TEST CIRCUIT



PULSE WIDTH (t_1) = 5 μs DUTY CYCLE = 2%

FIGURE 4 — TURN-OFF WAVEFORM



NOTE 1

When a transistor is held in a conductive state by a base current, I_B, a charge, Q_S, is developed or "stored" in the transistor. Q_S may be written: $Q_S = Q_1 + Q_V + Q_X$.

Q_1 is the charge required to develop the required collector current. This charge is primarily a function of alpha cutoff frequency. Q_V is the charge required to charge the collector-base feedback capacity. Q_X is excess charge resulting from overdrive, i.e., operation in saturation.

The charge required to turn a transistor "on" to the edge of saturation is the sum of Q_1 and Q_V which is defined as the active region charge, Q_A. $Q_A = I_{B1}t$, when the transistor is driven by a constant current step (I_{B1}) and $I_{B1} << \frac{I_C}{h_{FE}}$.

If I_B were suddenly removed, the transistor would continue to conduct until Q_S is removed from the active regions through an external path or through internal recombination. Since the internal recombination time is long compared to the ultimate capability of a transistor, a charge, Q_T, of opposite polarity, equal in magnitude, can be stored on an external capacitor, C, to neutralize the internal charge and considerably reduce the turn-off time of the transistor. Figure 3 shows the test circuit and Figure 4 the turn-off waveform. Given Q_T from Figure 13, the external C for worst-case turn-off in any circuit is: $C = Q_T/\triangle V$, where $\triangle V$ is defined in Figure 3.

"ON" CONDITION CHARACTERISTICS

FIGURE 5 — COLLECTOR SATURATION REGION

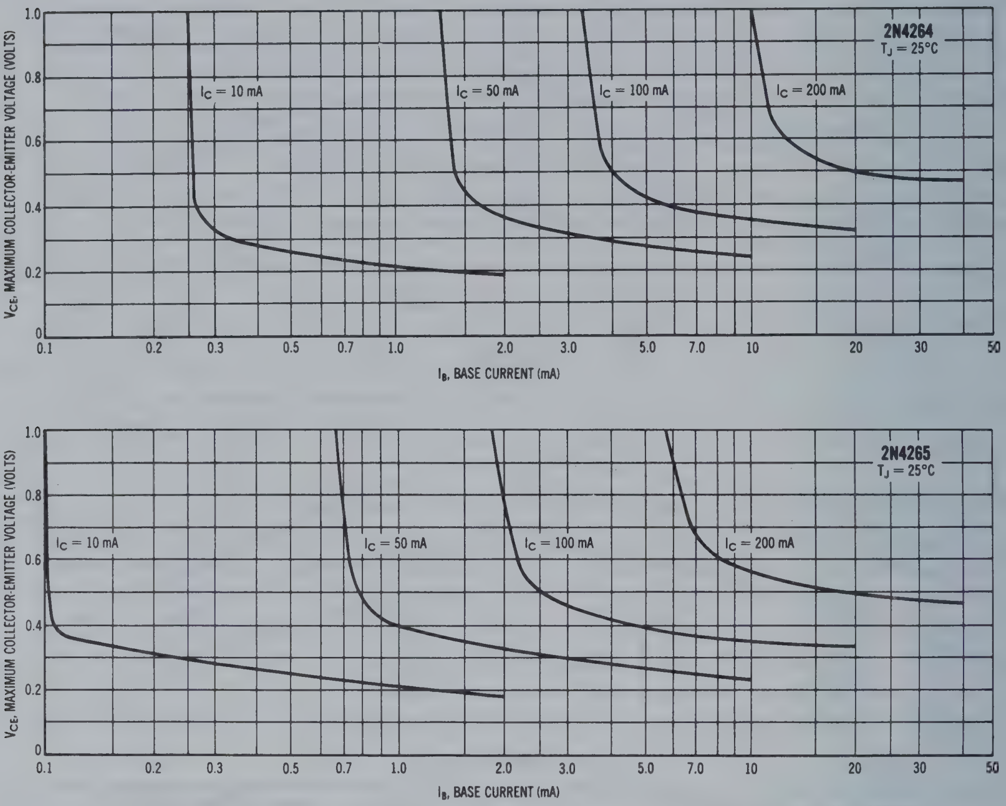


FIGURE 6 — SATURATION VOLTAGE LIMITS

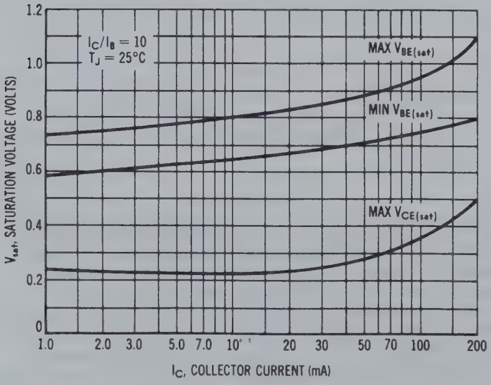
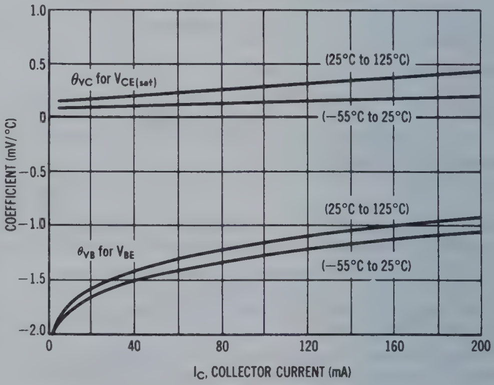


FIGURE 7 — TEMPERATURE COEFFICIENTS



DYNAMIC CHARACTERISTICS

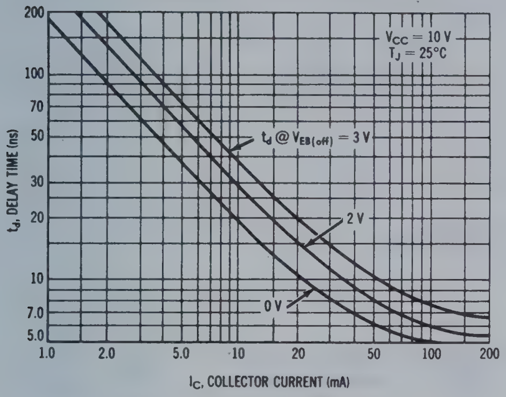


FIGURE 8 — DELAY TIME

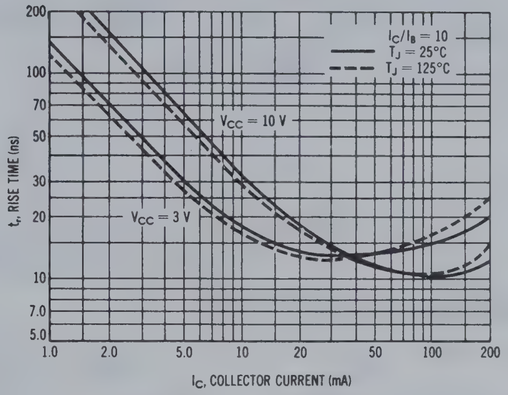


FIGURE 9 — RISE TIME

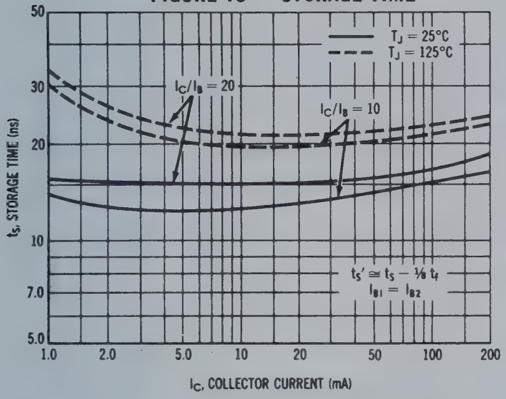


FIGURE 10 — STORAGE TIME

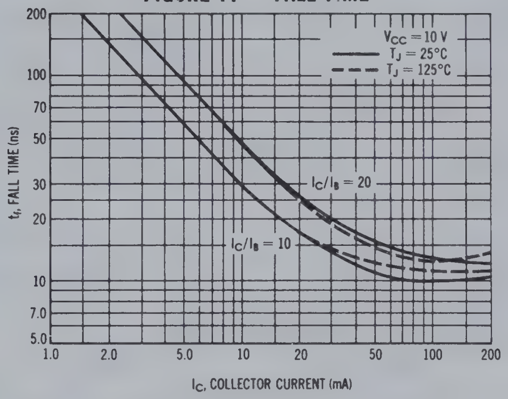


FIGURE 11 — FALL TIME

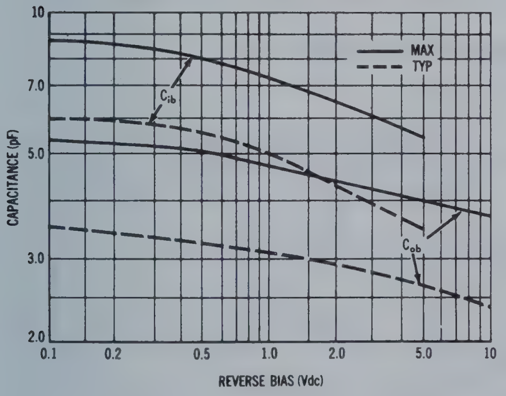


FIGURE 12 — JUNCTION CAPACITANCE

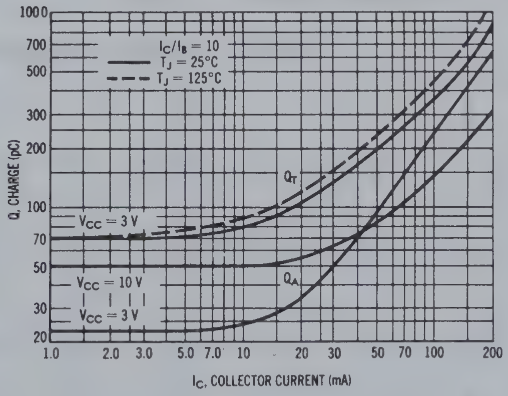
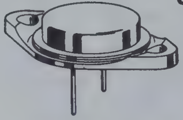


FIGURE 13 — MAXIMUM CHARGE DATA

2N4276 (GERMANIUM)
thru
2N4283

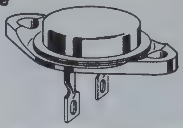
PNP germanium power transistors designed for high current applications requiring high-gain and low saturation voltages.

Collector connected to case



CASE 3A

(TO-3 modified)



CASE 161

(TO-41)

For units with lugs attached, specify devices MP4276 etc. (TO-41 package)

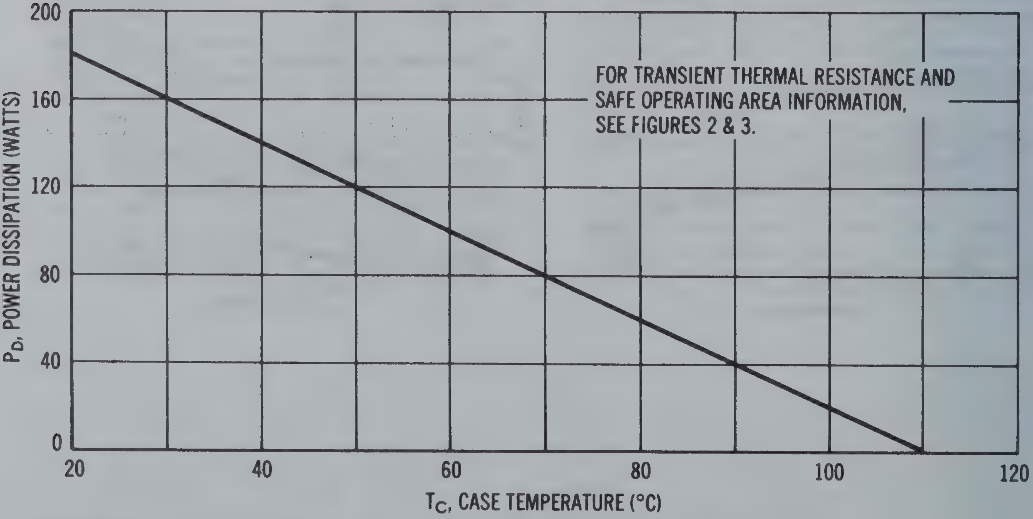
MAXIMUM RATINGS

Rating	Symbol	2N4276 2N4277	2N4278 2N4279	2N4280 2N4281	2N4282 2N4283	Unit
Collector-Emitter Voltage	V_{CEO}	20	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	30	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	20	25	30	40	Vdc
Collector Current — Continuous *	I_C*	← 60 →				Adc
Total Device Dissipation @ T_C = 25°C	P_D	← 170 →				Watts
Derate above 25°C		← 2.0 →				W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 — AVERAGE POWER-TEMPERATURE DERATING CURVE



*JEDEC Registered Values, For True Capability See Figure 3.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage†	BV_{CEO}†			Vdc
(I_C = 1.0 Adc, I_B = 0) 2N4276, 2N4277		20	-	
2N4278, 2N4279		30	-	
2N4280, 2N4281		45	-	
2N4282, 2N4283		60	-	
Collector-Emitter Breakdown Voltage	BV_{CES}			Vdc
(I_C = 300 mAdc, V_{BE} = 0) 2N4276, 2N4277		30	-	
2N4278, 2N4279		45	-	
2N4280, 2N4281		60	-	
2N4282, 2N4283		75	-	
Floating Potential	V_{EBF}			Vdc
(V_{CB} = 30 Vdc, I_E = 0) 2N4276, 2N4277		-	0.5	
(V_{CB} = 45 Vdc, I_E = 0) 2N4278, 2N4279		-	0.5	
(V_{CB} = 60 Vdc, I_E = 0) 2N4280, 2N4281		-	0.5	
(V_{CB} = 75 Vdc, I_E = 0) 2N4282, 2N4283		-	0.5	
Collector Cutoff Current	I_{CEX}			mAdc
(V_{CE} = 20 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4276, 2N4277		-	15	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4278, 2N4279		-	15	
(V_{CE} = 45 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4280, 2N4281		-	15	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4282, 2N4283		-	15	
Collector Cutoff Current	I_{CBO}			mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)		-	0.2	
(V_{CB} = 30 Vdc, I_E = 0) 2N4276, 2N4277		-	4.0	
(V_{CB} = 45 Vdc, I_E = 0) 2N4278, 2N4279		-	4.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N4280, 2N4281		-	4.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N4282, 2N4283		-	4.0	
Emitter Cutoff Current	I_{EBO}			mAdc
(V_{BE} = 20 Vdc, I_C = 0) 2N4276, 2N4277		-	4.0	
(V_{BE} = 20 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 25 Vdc, I_C = 0) 2N4278, 2N4279		-	4.0	
(V_{BE} = 25 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 30 Vdc, I_C = 0) 2N4280, 2N4281		-	4.0	
(V_{BE} = 30 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 40 Vdc, I_C = 0) 2N4282, 2N4283		-	4.0	
(V_{BE} = 40 Vdc, I_C = 0, T_C = +71°C)		-	15	
ON CHARACTERISTICS				
DC Current Gain†	h_{FE}†			-
(I_C = 15 Adc, V_{CE} = 2.0 Vdc) 2N4276, 2N4278, 2N4280, 2N4282		60	180	
2N4277, 2N4279, 2N4281, 2N4283		120	240	
(I_C = 60 Adc, V_{CE} = 2.0 Vdc)		15	-	
Collector-Emitter Saturation Voltage†	$V_{CE(sat)}$†			Vdc
(I_C = 15 Adc, I_B = 1.0 Adc)		-	0.15	
(I_C = 60 Adc, I_B = 6.0 Adc)		-	0.3	
Base-Emitter Saturation Voltage†	$V_{BE(sat)}$†			Vdc
(I_C = 15 Adc, I_B = 1.0 Adc)		-	0.6	
(I_C = 60 Adc, I_B = 6.0 Adc)		-	1.0	
SMALL SIGNAL CHARACTERISTICS				
Common-Emitter Cutoff Frequency (I_C = 15 Adc, V_{CE} = 2.0 Vdc)	$f_{\alpha e}$	2.0	-	kHz

† To avoid excessive heating of the collector junction, perform test with pulse method.

FIGURE 2 — TRANSIENT THERMAL RESISTANCE

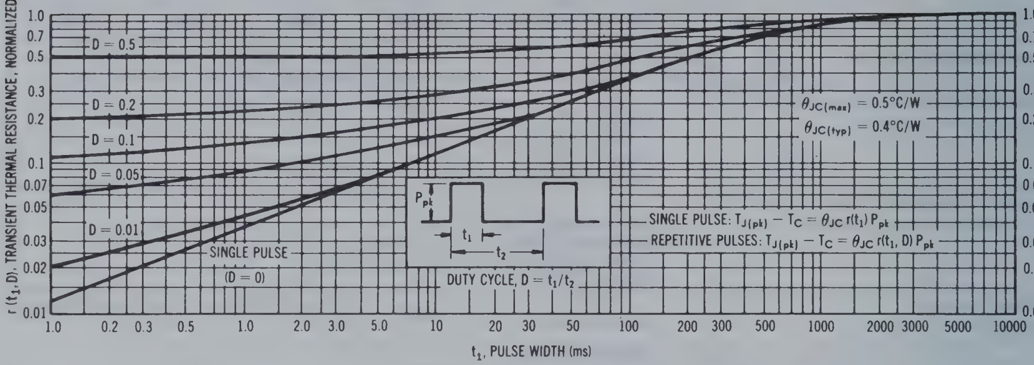
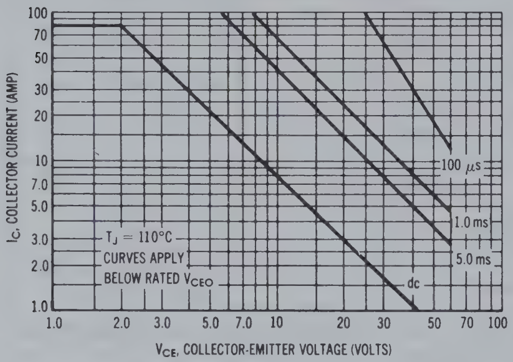


FIGURE 3 — ACTIVE REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e. the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 3 is based on $T_{J(pk)} = 110°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 110°C$. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 4 — SWITCHING TEST CIRCUIT

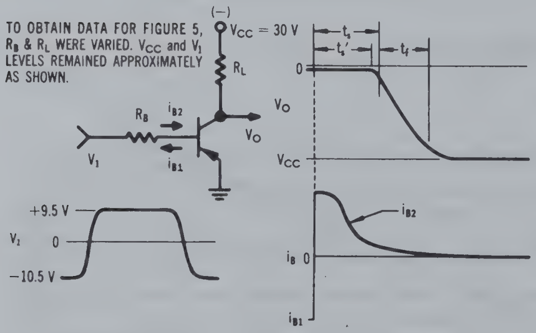
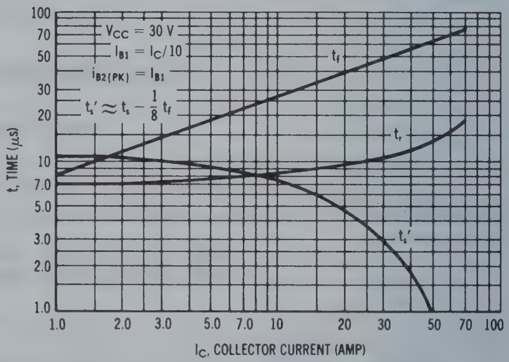

TO OBTAIN DATA FOR FIGURE 5, RB & RL WERE VARIED. VCC and V1 LEVELS REMAINED APPROXIMATELY AS SHOWN.
(−)
VCC = 30 V
RL
RB
iB2
iB1
V1
VO
+9.5 V
V1
0
−10.5 V
ts
ts'
tf
0
VO
VCC
iB2
iB 0
iB1

FIGURE 5 — SWITCHING TIMES



The switching performance of this transistor is determined primarily by the gain-bandwidth product, f_T*, and the behavior of the base-spreading resistance, r_B'.

In the case of rise time, the base-spreading resistance plays a small part, and the test circuit delivers a constant current step of turn-on current to the transistor (I_{B1}). Therefore, the curve of t_r on Figure 5 follows theory closely, i.e.:

$$t_r \approx 0.8 \frac{I_C}{I_{B1}} \cdot \frac{1}{2\pi f_T}$$

From the curve, it can be seen that f_T is roughly constant with current; using the equation, its large signal value can be calculated to be approximately 120 kHz at the 20-Amp level. A lower supply voltage will increase rise time slightly.

Turn-off time is slow because of conductivity modulation which occurs in the base region. When the transistor is held "on" in saturation, the base region becomes filled with excess charge; i.e., charge in excess of that necessary to sustain the circuit limited value of I_C. As a result, the base resistivity and consequently r_B' become very low. During turn off, as the excess charge is reduced, the accompanying, increase in resistivity causes a marked reduction in the turn-off current, i_{B2}, as can be seen from the waveforms of Figure 4. During fall time, the i_{B2} current is very low causing an extended fall time.

Only a slight improvement in turn-off performance is achieved with a "speed-up" capacitor placed across R_B. This unusual behavior occurs because r_B' limits the amount of reverse current which can be achieved. Also, it seems evident that r_B' increases with applied reverse current, so that efforts to speed up the turn-off behavior are somewhat futile.

In most applications, switching time will be close to the values shown on Figure 5. Delay time is not shown as it is negligible in comparison to the other times.

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* $f_T \approx f_{\alpha e} \times h_{fe}$

TYPICAL DC CHARACTERISTICS

FIGURE 6 — DC CURRENT GAIN

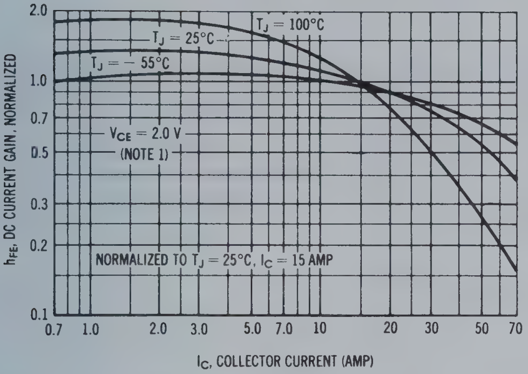


FIGURE 7 — COLLECTOR SATURATION REGION

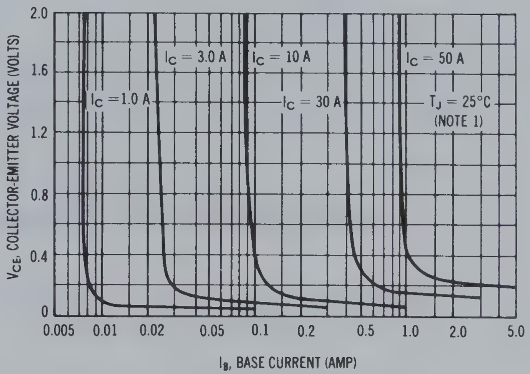


FIGURE 8 — EFFECTS OF BASE-EMITTER RESISTANCE

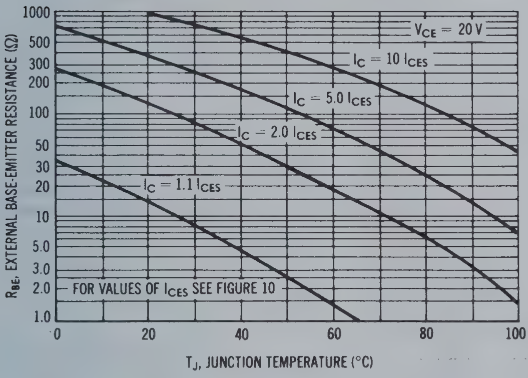


FIGURE 9 — "ON" VOLTAGES

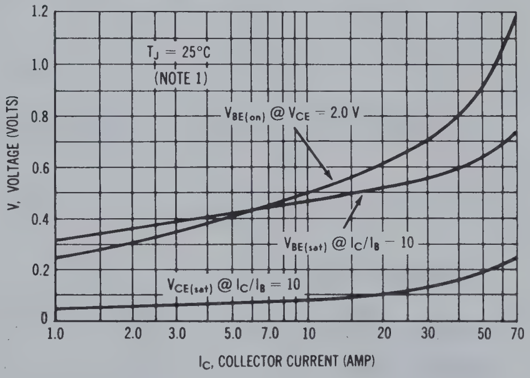
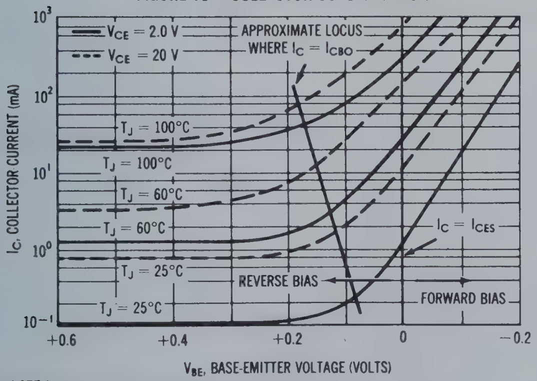
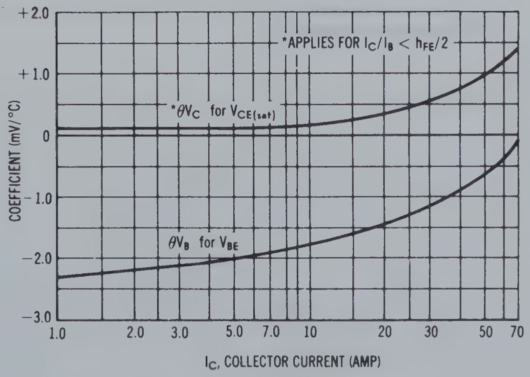


FIGURE 10 — COLLECTOR CUTOFF REGION



NOTE 1: Data is obtained from pulse tests and adjusted to nullify the effect of I_{CBO}.

FIGURE 11 — TEMPERATURE COEFFICIENTS



2N4342 (SILICON)

SILICON P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

Depletion Mode (Type A) Junction Field-Effect Transistor designed primarily for high-gain audio frequency applications.

- High Forward Transadmittance —
  $|y_{fs}| = 2.0$ mmhos (Min) @ $V_{DS} = -10$ Vdc (2N4342)
- Low Noise Figure —
  NF = 1.5 dB (Max) @ f = 100 Hz
- Low Drain-Source "ON" Resistance —
  $r_{ds(on)} = 700$ Ohms (Max) @ f = 1.0 kHz (2N4342)

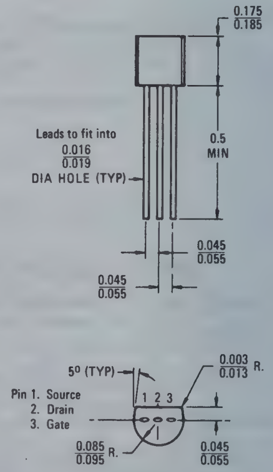
P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-25	Vdc
Drain-Gate Voltage	V_{DG}	-25	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	25	Vdc
Forward Gate Current	I_{GF}	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	200 2.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +125	°C

*Indicates JEDEC Registered Data.


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
0.5
MIN
0.045
0.055
0.045
0.055
5° (TYP)
0.003
0.013 R.
Pin 1. Source
2. Drain
3. Gate
1 2 3
0.085
0.095 R.
0.045
0.055

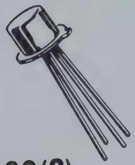
CASE 29 (7)
TO-92

***ELECTRICAL CHARACTERISTICS** ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage ($I_G = 10\ \mu Adc$, $V_{DS} = 0$)	$V_{(BR)GSS}$	25	–	Vdc
Gate-Source Cutoff Voltage ($V_{DS} = -10$ Vdc, $I_D = 1.0\ \mu Adc$)	$V_{GS(off)}$	1.0	5.5	Vdc
Gate Reverse Current ($V_{GS} = 15$ Vdc, $V_{DS} = 0$)	I_{GSS}	–	10	nAdc
($V_{GS} = 15$ Vdc, $V_{DS} = 0$, $T_A = 65^{\circ}C$)		–	0.5	µAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current ($V_{DS} = -10$ Vdc, $V_{GS} = 0$)	I_{DSS}	4.0	12	mAdc
Gate-Source Voltage ($V_{DS} = -10$ Vdc, $I_D = 0.4$ mAdc)	V_{GS}	0.7	5.0	Vdc
($V_{DS} = -10$ Vdc, $I_D = 1.0$ mAdc)				
SMALL-SIGNAL CHARACTERISTICS				
Drain-Source "ON" Resistance ($V_{GS} = 0$, $I_D = 0$, f = 1.0 kHz)	$r_{ds(on)}$	–	700	Ohms
Forward Transadmittance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	y_{fs}	2000	6000	µmhos
Forward Transconductance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	Re(y_{fs})	1500	–	µmhos
Output Admittance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	y_{os}	–	75	µmhos
Input Capacitance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{iss}	–	20	pF
Reverse Transfer Capacitance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{rss}	–	5.0	pF
Common-Source Noise Figure ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, $R_G = 1.0$ Megohm, f = 100 Hz, BW = 15 Hz)	NF	–	1.5	dB
		–		
Equivalent Short-Circuit Input Noise Voltage ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 100 Hz, BW = 15 Hz)	E_n	–	0.08	$\mu V/\sqrt{Hz}$

*Indicates JEDEC Registered Data.

2N4351 (SILICON)



CASE 20(2)
(TO-72)

Silicon N-channel MOS field effect transistors, designed for enhancement-mode operation in low power switching applications. The 2N4351 is complementary with type 2N4352 .

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	± 30	Vdc
Drain Current	I_D	30	mAdc
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Power Dissipation at T_C = 25°C Derate about 25°C	P_D	800 4.56	mW mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Substrate connected to source.

Characteristic	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = 10 μA, V_{GS} = 0)	—	$V_{(BR)DSS}$	25	—	Vdc
Gate Leakage Current (V_{GS} = ±30 Vdc, V_{DS} = 0)	—	I_{GSS}	—	10	pAdc
Zero-Gate-Voltage Drain Current (V_{DS} = 10 V, V_{GS} = 0)	—	I_{DSS}	—	10	nAdc
ON CHARACTERISTICS					
Gate-Source Threshold Voltage (V_{DS} = 10 V, I_D = 10 μA)	—	$V_{GS(TH)}$	1.0	5.0	Vdc
"ON" Drain Current (V_{GS} = 10 V, V_{DS} = 10 V)	3	$I_{D(on)}$	3.0	—	mAdc
Drain-Source "ON" Voltage (I_D = 2 mA, V_{GS} = 10 V)	—	$V_{DS(on)}$	—	1.0	Vdc
SMALL SIGNAL CHARACTERISTICS					
Drain-Source Resistance (V_{GS} = 10 V, I_D = 0, f = 1 kHz)	4	$r_{ds(on)}$	—	300	ohms
Forward Transfer Admittance (V_{DS} = 10 V, I_D = 2 mA, f = 1 kHz)	1	$\|y_{fs}\|$	1000	—	μmho
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	2	C_{rss}	—	1.3	pF
Input Capacitance (V_{DS} = 10 V, V_{GS} = 0, f = 140 kHz)	2	C_{iss}	—	5.0	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$ = 10 V, f = 140 kHz)	—	$C_{d(sub)}$	—	5.0	pF

SWITCHING CHARACTERISTICS

Turn-On Delay	I_D = 2.0 mAdc, V_{DS} = 10 Vdc, V_{GS} = 10 Vdc (See Figure 10; Times Circuit Determined)	6, 10	t_{d1}	—	45	ns
Rise Time		7, 10	t_r	—	65	ns
Turn-Off Delay		8, 10	t_{d2}	—	60	ns
Fall Time		9, 10	t_f	—	100	ns

FIGURE 1 — FORWARD TRANSFER ADMITTANCE

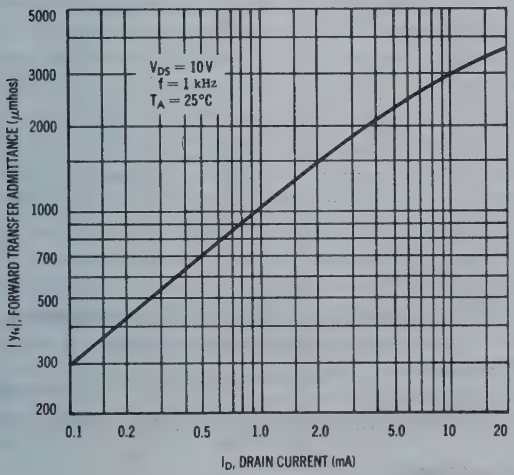


FIGURE 2 — CAPACITANCE

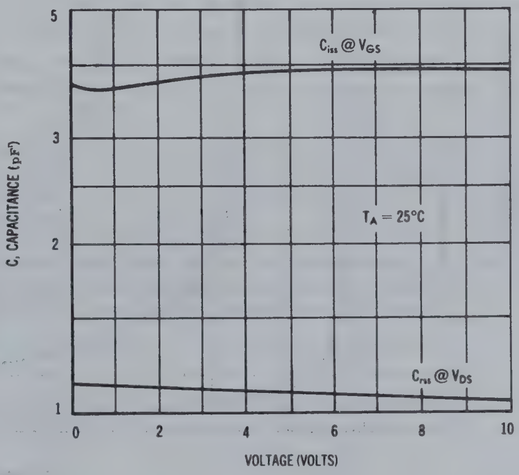


FIGURE 3 — TRANSFER CHARACTERISTICS

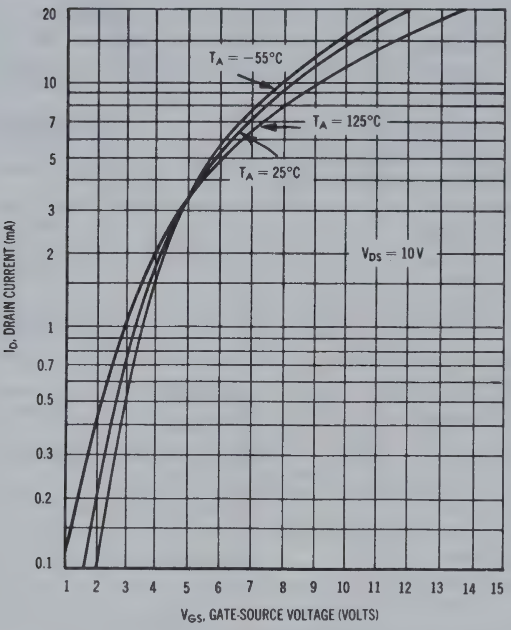


FIGURE 4 — DRAIN SOURCE "ON" RESISTANCE

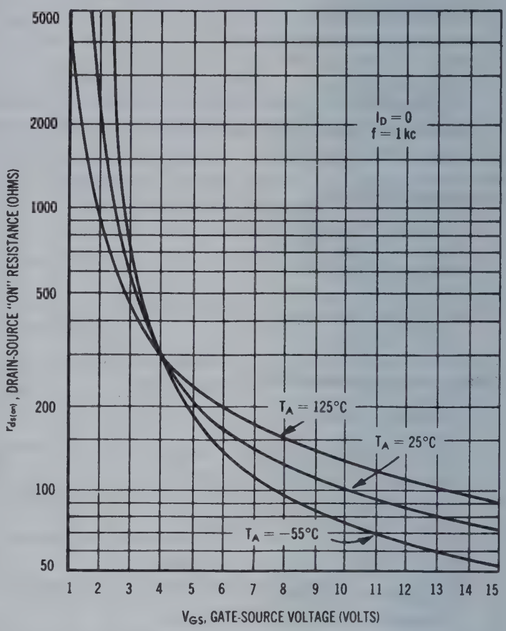
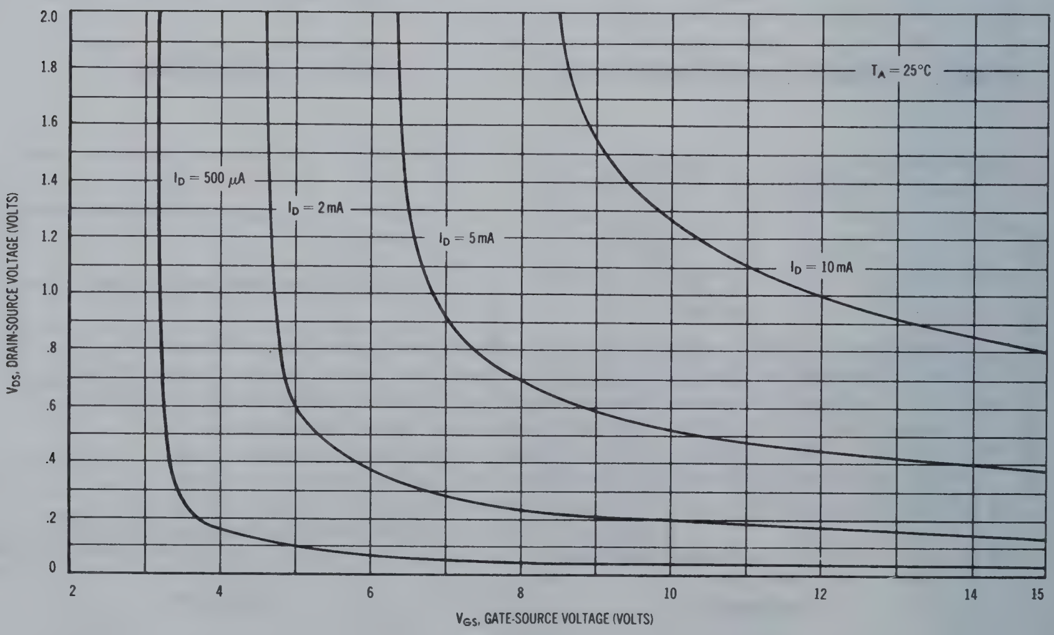


FIGURE 5 — "ON" DRAIN-SOURCE VOLTAGE



SWITCHING CHARACTERISTICS

($T_A = 25^{o}C$)

FIGURE 6 — TURN-ON DELAY TIME

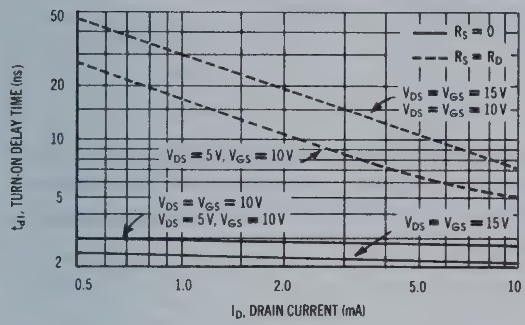


FIGURE 7 — RISE TIME

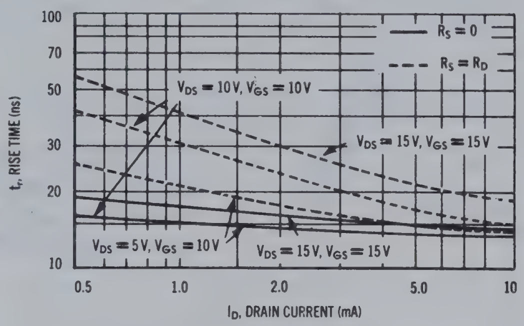


FIGURE 8 — TURN-OFF DELAY TIME

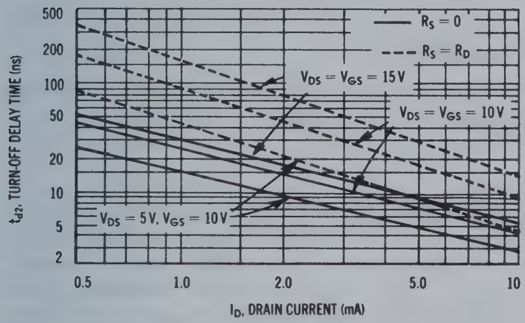


FIGURE 9 — FALL TIME

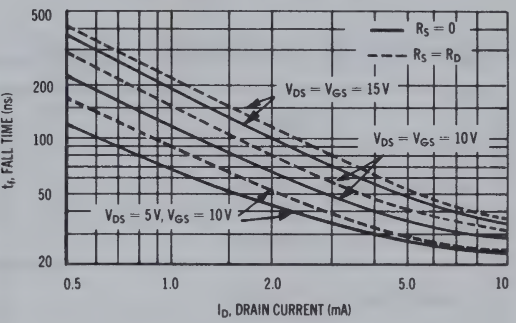
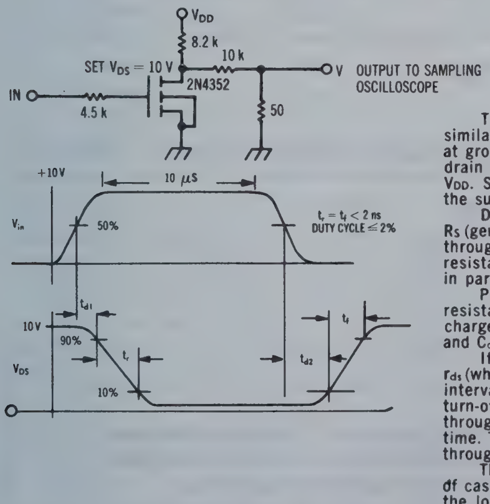


FIGURE 10 — SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 10. At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

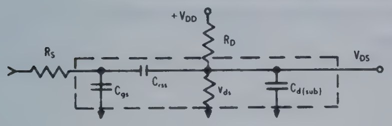
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_S (generator impedance) (Figure 11). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_S and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with r_{ds}. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 4) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

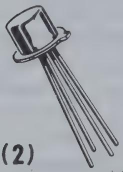
If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_S = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_S = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_S = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 11 — SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL



2N4352 (SILICON)



CASE 20 (2)
(TO-72)

Silicon P-channel MOS field-effect transistor designed for enhancement-mode operation in low-power switching applications. The 2N4352 is complementary with type 2N4351.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	± 30	Vdc
Drain Current	I_D	30	mAdc
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Power Dissipation @ T_C = 25°C Derate above 25°C	P_D	800 4.56	mW mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to + 175	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Substrate connected to source.

Characteristic	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = -10 μA, V_{GS} = 0)	—	$V_{(BR)DSS}$	25	—	Vdc
Gate Leakage Current (V_{GS} = ±30 V, V_{DS} = 0)	—	I_{GSS}	—	10	pAdc
Zero-Gate Voltage Drain Current (V_{DS} = -10 V, V_{GS} = 0)	—	I_{DSS}	—	10	nAdc
ON CHARACTERISTICS					
Gate-Source Threshold Voltage (V_{DS} = -10 V, I_D = -10 μA)	—	$V_{GS(TH)}$	1.0	5.0	Vdc
"ON" Drain Current (V_{GS} = -10 V_{DS} = -10 V)	3	$I_{D(on)}$	3.0	—	mA
Drain-Source "ON" Voltage (I_D = -2.0 mA, V_{GS} = -10 V)	5	$V_{DS(on)}$	—	1.0	V
SMALL SIGNAL CHARACTERISTICS					
Drain-Source Resistance (V_{GS} = -10 V, I_D = 0, f = 1 kHz)	4	$r_{ds(on)}$	—	600	ohms
Forward Transfer Admittance (V_{DS} = -10 V, I_D = 2 mA, f = 1 kHz)	1	$\lvert y_{fs} \rvert$	1000	—	μmho
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	2	C_{rss}	—	1.3	pF
Input Capacitance (V_{DS} = -10 V, V_{GS} = 0, f=140 kHz)	2	C_{iss}	—	5.0	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$= -10 V, f= 140 kHz)	—	$C_{d(sub)}$	—	4.0	pF
SWITCHING CHARACTERISTICS					
Turn-On Delay I_D = -2.0 mAdc, V_{DS} = -10 Vdc, V_{GS} = -10 V (See Figure 10, Times Circuit Determined)	6, 10	t_{d1}	—	45	ns
Rise Time	7, 10	t_r	—	65	ns
Turn-Off Delay	8, 10	t_{d2}	—	60	ns
Fall Time	9, 10	t_f	—	100	ns

FIGURE 1 — FORWARD TRANSFER ADMITTANCE

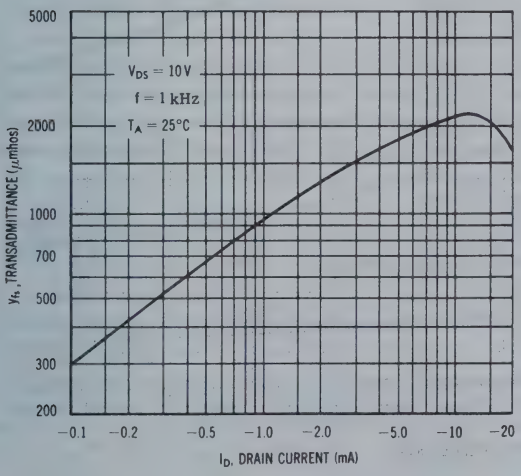


FIGURE 2 — CAPACITANCE

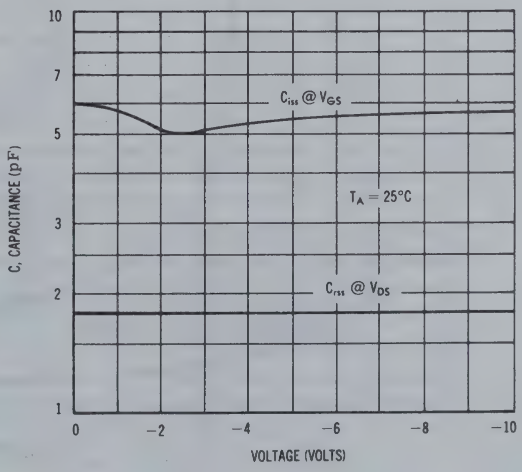


FIGURE 3 — TRANSFER CHARACTERISTICS

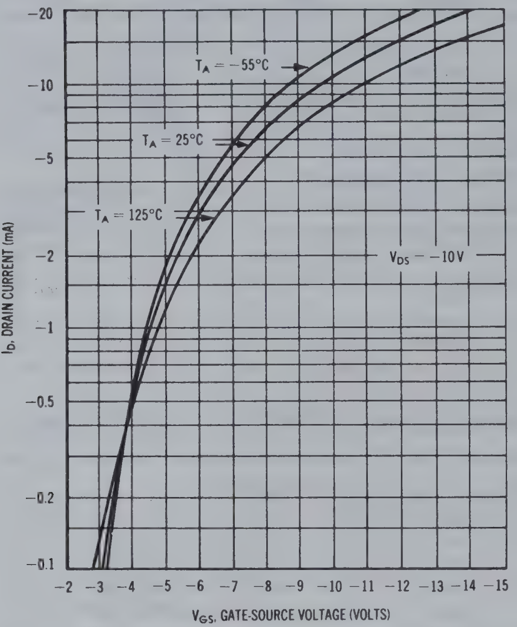


FIGURE 4 — DRAIN SOURCE "ON" RESISTANCE

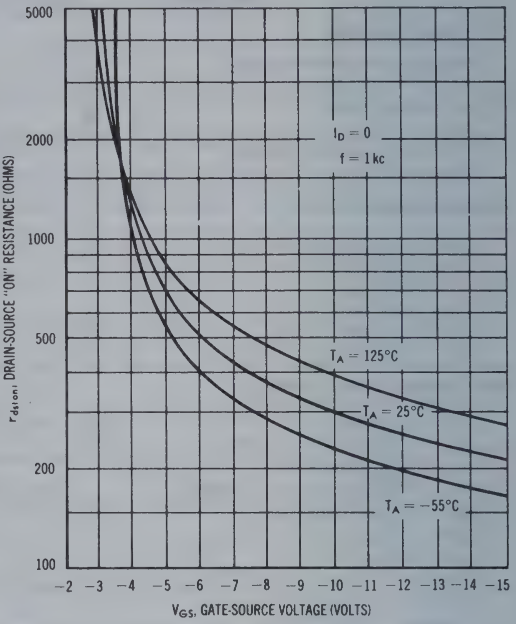
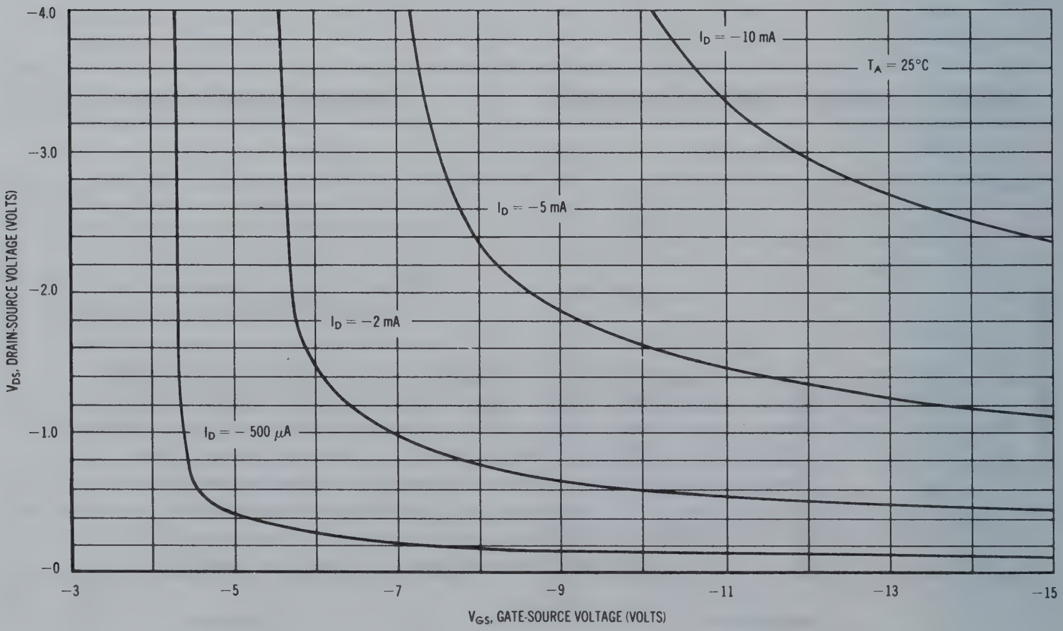


FIGURE 5 — "ON" DRAIN-SOURCE VOLTAGE



SWITCHING CHARACTERISTICS

($T_A = 25°C$)

FIGURE 6 — TURN-ON DELAY TIME

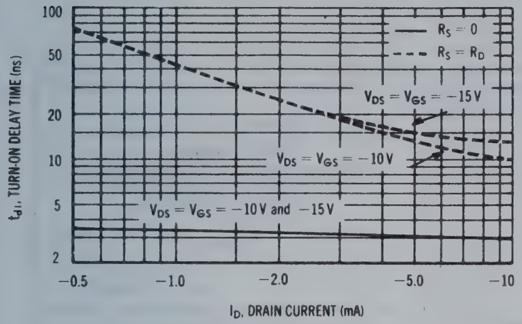


FIGURE 7 — RISE TIME

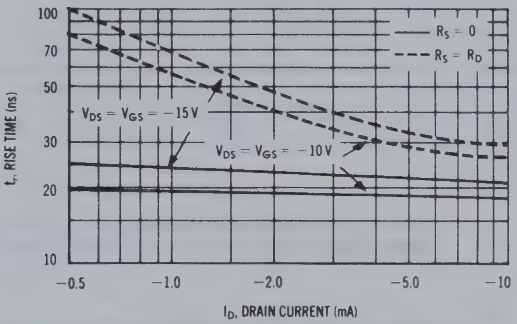


FIGURE 8 — TURN-OFF DELAY TIME

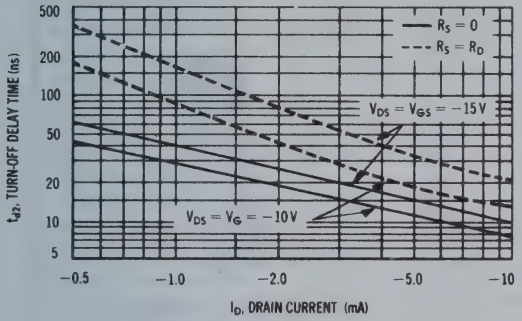


FIGURE 9 — FALL TIME

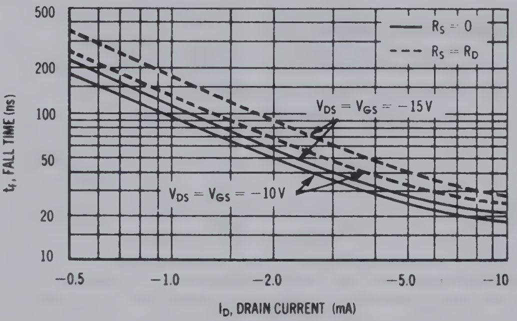
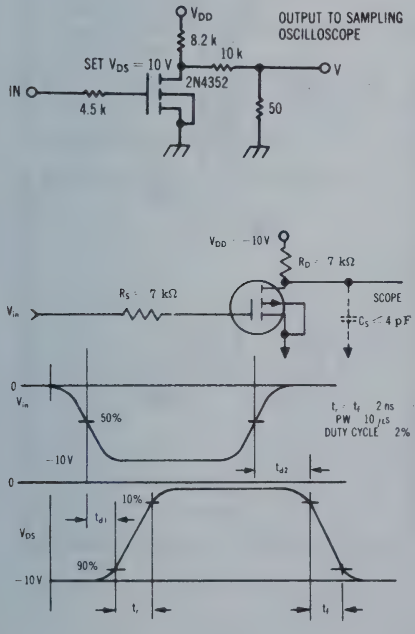


FIGURE 10 — SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 10. At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

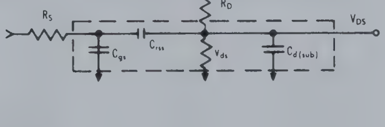
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_S (generator impedance) (Figure 11). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_S and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with r_{ds}. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 4) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_S = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_S = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_S = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 11 — SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL



2N4360 (SILICON)

SILICON P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

Depletion Mode (Type A) Junction Field-Effect Transistors designed primarily for low-power audio frequency applications

- Forward Transadmittance —
  $|y_{fs}| = 2.0$ mmhos (Min) @ $V_{DS} = -10$ Vdc
- Low Reverse Transfer Capacitance —
  $C_{rss} = 5.0$ pF (Max) @ $V_{DS} = -10$ Vdc

P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

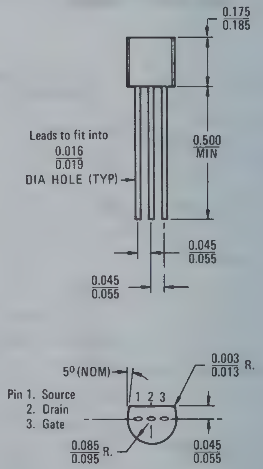
(Type A)

Case 29 with leads formed to a TO-18 configuration.

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-20	Vdc
Drain-Gate Voltage	V_{DG}	-20	Vdc
Reverse Gate-Source Voltage	V_{GSR}	20	Vdc
Gate Current	I_G	50	mAdc
Total Device Dissipation @ $T_A = 25^\circ$C Derate above 25°C	P_D	200 2.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +125	°C

*Indicates JEDEC Registered Data.


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
0.500
MIN
0.045
0.055
0.045
0.055
5° (NOM)
0.003
0.013 R.
Pin 1. Source
2. Drain
3. Gate
1 2 3
0.085
0.095 R.
0.045
0.055

CASE 29(7)
TO-92

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	20	–	Vdc
Gate-Source Cutoff Voltage (V_{DS} = –10 Vdc, I_D = 1.0 μAdc)	$V_{GS(off)}$	0.7	10	Vdc
Gate Reverse Current	I_{GSS}			
(V_{GS} = 15 Vdc, V_{DS} = 0)		–	10	nAdc
(V_{GS} = 15 Vdc, V_{DS} = 0, T_A = 65°C)		–	0.5	μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current (Note 1) (V_{DS} = –10 Vdc, V_{GS} = 0)	I_{DSS}	3.0	30	mAdc
Gate-Source Voltage (V_{DS} = –10 Vdc, I_D = 0.3 mAdc)	V_{GS}	0.4	9.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	$r_{ds(on)}$	–	700	Ohms
Forward Transadmittance (Note 1) (V_{DS} = –10 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{fs}\|$	2000	8000	μmhos
Forward Transconductance (V_{DS} = –10 Vdc, V_{GS} = 0, f = 1.0 MHz)	$Re(y_{fs})$	1500	–	μmhos
Output Admittance (V_{DS} = –10 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$	–	100	μmhos
Input Capacitance (V_{DS} = –10 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	–	20	pF
Reverse Transfer Capacitance (V_{DS} = –10 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	–	5.0	pF
Common-Source Noise Figure (V_{DS} = –10 Vdc, I_D = 1.0 mAdc, R_G = 1.0 Megohm, f = 100 Hz)	NF	–	5.0	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = –10 Vdc, I_D = 1.0 mAdc, f = 100 Hz, BW = 15 Hz)	E_n	–	0.19	$\mu V/\sqrt{Hz}$

*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width ≤ 630 ms, Duty Cycle ≤ 10%.

2N4361 thru 2N4368 PNPN (SILICON)
2N4371 thru 2N4378

THYRISTORS
SILICON CONTROLLED RECTIFIERS

. . . designed for high power industrial and consumer applications in power and speed controls such as welders, furnaces, motors, space heaters and other equipment where control of high current is needed.

THYRISTORS
PNPN

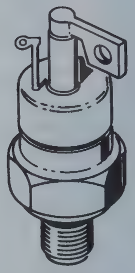
110 AMPERES RMS
100 thru 1400 VOLTS**

MAXIMUM RATINGS

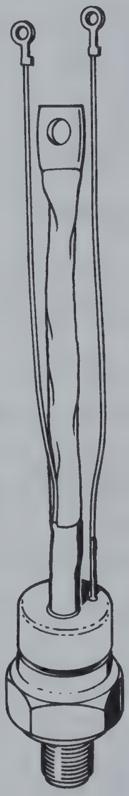
Rating		Symbol	Value	Unit
*Repetitive Peak Reverse Blocking Voltage	2N4361, 2N4371 2N4362, 2N4372 2N4363, 2N4373 2N4364, 2N4374 2N4365, 2N4375 2N4366, 2N4376 2N4367, 2N4377 2N4368, 2N4378	V_{RRM}(1)	100 200 400 600 800 1000 1200 1400	Volts
Non-Repetitive Peak Reverse Blocking Voltage ($t \leq 5.0$ ms)	2N4361, 2N4371 2N4362, 2N4372 2N4363, 2N4373 2N4364, 2N4374 2N4365, 2N4375 2N4366, 2N4376 2N4367, 2N4377 2N4368, 2N4378	V_{RSM}	200 300 500 700 900 1100 1300 1500	Volts
Forward Current RMS, $T_C = 75^oC$		$I_{T(RMS)}$	110	Amp
*Peak Surge Current (One cycle, 60 Hz) (T_J = -40 to +125°C)		I_{TSM}	1600	Amp
Circuit Fusing Considerations (T_J = -40 to +125°C)	(t = 1.5 ms) (t = 8.3 ms)	I^2t	8400 10,700	A^2s
*Peak Gate Power		P_{GFM}	15	Watts
*Average Gate Power		$P_{GF(AV)}$	3.0	Watt
*Peak Forward Gate Current		I_{GFM}	4.0	Amp
*Peak Reverse Gate Voltage		V_{GRM}	5.0	Volts
*Operating Junction Temperature Range		T_J	-40 to +125	°C
*Storage Temperature Range		T_{stg}	-40 to +150	°C
Stud Torque		–	130	in. lb.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.28	°C/W



2N4371
SERIES
CASE 246
TO-83



2N4361
SERIES
CASE 219
TO-94

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*Indicates JEDEC Registered Data.

**Consult factory for higher and intermediate voltages.

(1) Ratings apply for zero or negative gate voltage. Devices should not be tested for blocking capability in a manner such that the voltage applied exceeds the rated blocking voltage.

(2) Devices should not be operated with a positive bias applied to the gate concurrent with a negative potential applied to the anode.

(3) Reliable operation can be impaired if torque rating is exceeded, terminal tubes bent, or seal broken.

ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
*Peak Forward Blocking Voltage ($T_J = 125^oC$)		V_{DRM}(1)				Volts
	2N4361, 2N4371		100	–	–	
	2N4362, 2N4372		200	–	–	
	2N4363, 2N4373		400	–	–	
	2N4364, 2N4374		600	–	–	
	2N4365, 2N4375		800	–	–	
	2N4366, 2N4376		1000	–	–	
	2N4367, 2N4377		1200	–	–	
	2N4368, 2N4378		1400	–	–	
*Peak Forward Blocking Current (Rated V_{DRM}, with gate open, $T_J = 125^oC$)		I_{DRM}	–	–	10	mA
*Peak Reverse Blocking Current (Rated V_{RRM}, with gate open, $T_J = 125^oC$)		I_{RRM}	–	–	10	mA
Forward "On" Voltage (I_T = 50 A Peak, $T_J = 25^oC$)		V_T	–	–	1.6	Volts
Forward "On" Voltage (I_{TM} = 500 A Peak $T_J = 25^oC$)		V_{TM}	–	–	2.5	Volts
Gate Trigger Current (Anode Voltage = 12 V, R_L = 3.0 ohms)		I_{GT}	–	–	200	mA
Gate Trigger Voltage (Anode Voltage = 12 V, R_L = 3.0 ohms)		V_{GT}	–	–	3.0	Volts
Holding Current (Anode Voltage = 12 V, gate open, $T_J = 125^oC$)		I_H	–	30	–	mA
*Non-Triggering Gate Voltage (Anode Voltage = Rated V_{DM}, R_L = 100 ohms, $T_J = 125^oC$)		V_{GD}	–	–	0.15	Volts
Turn-Off Time (I_{TM} = 50 A, I_R = 20 A, $T_J = 125^oC$)		t_q	–	40	–	μs
*Forward Voltage Application Rate (Exponential to V_{DRM})		dv/dt	100	–	–	V/μs

*Indicates JEDEC Registered Data.

(1) Ratings apply for zero or negative gate voltage. Devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

DERATING AND DISSIPATION FOR RESISTIVE AND INDUCTIVE LOADS (f = 50 to 400 Hz, SQUARE WAVE)

FIGURE 1 – CURRENT DERATING

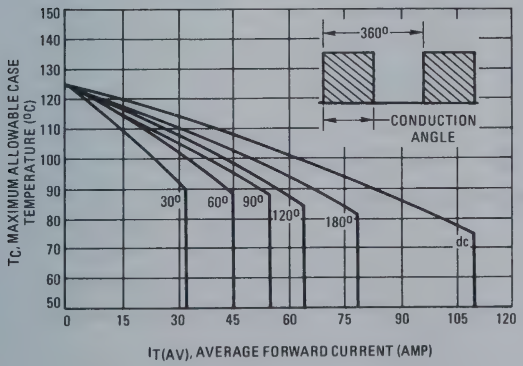
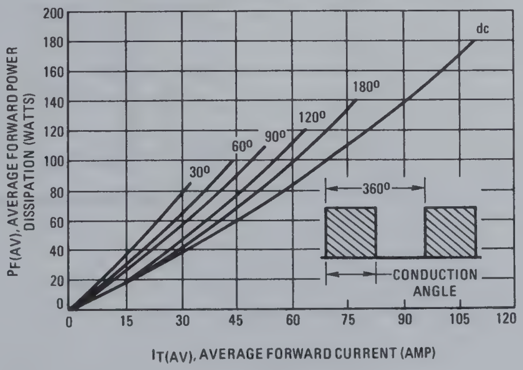


FIGURE 2 – FORWARD POWER DISSIPATION



DERATING AND DISSIPATION FOR RESISTIVE AND INDUCTIVE LOADS (f = 50 to 400 Hz, SINE WAVE)

FIGURE 3 – CURRENT DERATING

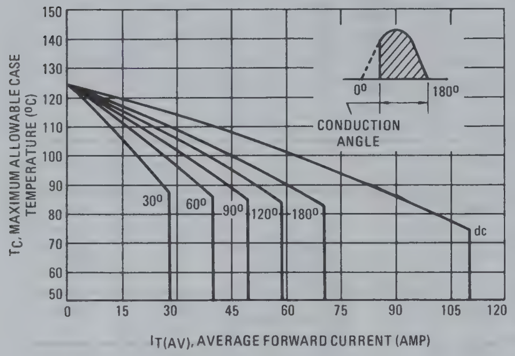


FIGURE 4 – FORWARD POWER DISSIPATION

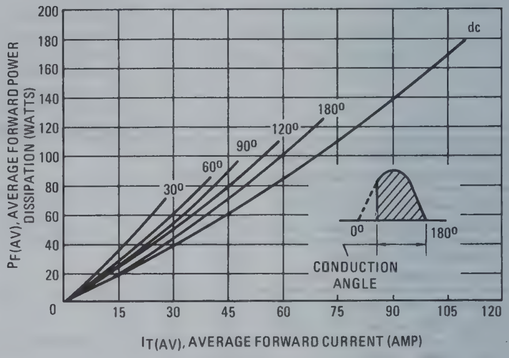
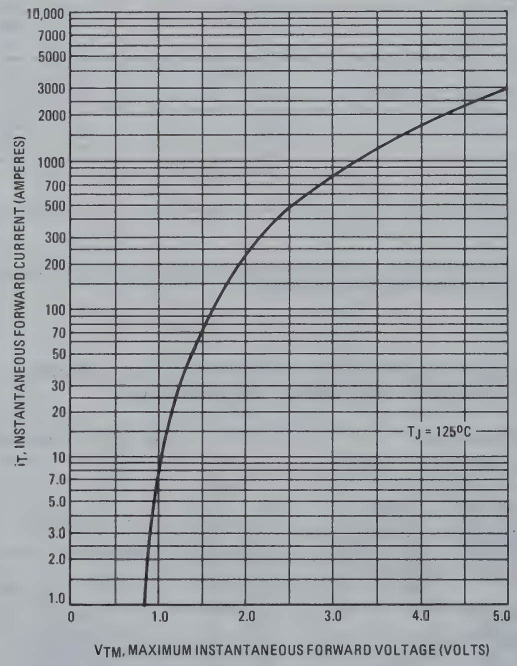
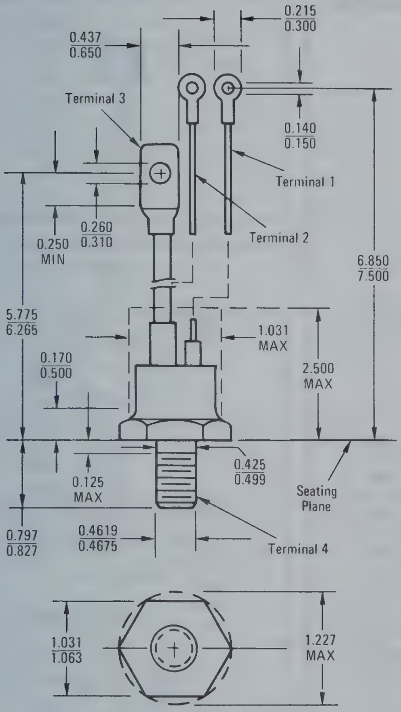


FIGURE 5 – FORWARD CONDUCTION CHARACTERISTIC



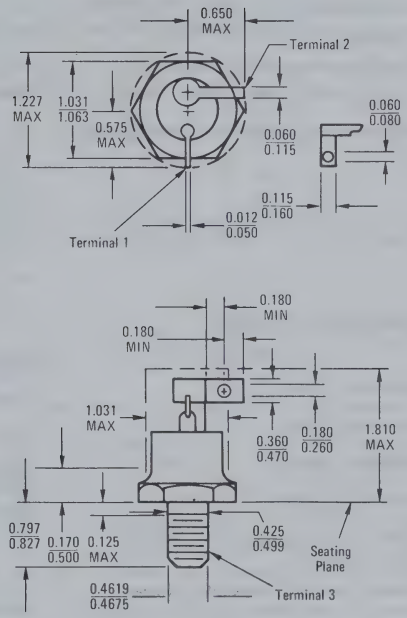
2N4361 thru 2N4368/2N4371 thru 2N4378 (continued)


0.215
0.300
0.437
0.650
Terminal 3
0.140
0.150
Terminal 1
0.250
MIN
0.260
0.310
Terminal 2
6.850
7.500
5.775
6.265
1.031
MAX
0.170
0.500
2.500
MAX
0.125
MAX
0.425
0.499
Seating
Plane
0.797
0.827
0.4619
0.4675
Terminal 4
1.031
1.063
1.227
MAX

To convert inches to millimeters multiply by 25.4
All JEDEC dimensions and notes apply

CASE 219-01
TO-94

TERMINAL 1 – GATE (WHITE)
TERMINAL 2 – CATHODE POTENTIAL (RED)
TERMINAL 3 – CATHODE (RED)
TERMINAL 4 – ANODE


0.650
MAX
Terminal 2
1.227
MAX
1.031
1.063
0.575
MAX
0.060
0.115
0.060
0.080
0.115
0.160
0.012
0.050
Terminal 1
0.180
MIN
0.180
MIN
1.031
MAX
0.360
0.470
0.180
0.260
1.810
MAX
0.797
0.827
0.170
0.500
0.125
MAX
0.425
0.499
Seating
Plane
0.4619
0.4675
Terminal 3

To convert inches to millimeters multiply by 25.4
All JEDEC dimensions and notes apply

CASE 246-01
TO-83

TERMINAL 1 – GATE
TERMINAL 2 – CATHODE
TERMINAL 3 – ANODE

2N4391 (SILICON)
2N4392
2N4393

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

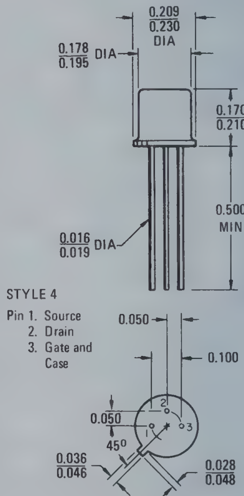
Depletion Mode (Type A) Junction Field-Effect Transistors designed for chopper and high-speed switching applications.

- Low Drain-Source "On" Resistance —
  $r_{ds(on)}$ = 30 Ohms (Max) @ f = 1.0 kHz (2N4391)
- Low Gate Reverse Current —
  I_{GSS} = 0.1 nAdc (Max) @ V_{GS} = 20 Vdc
- Guaranteed Switching Characteristics

**N-CHANNEL
JUNCTION FIELD-EFFECT
TRANSISTORS
(Type A)**

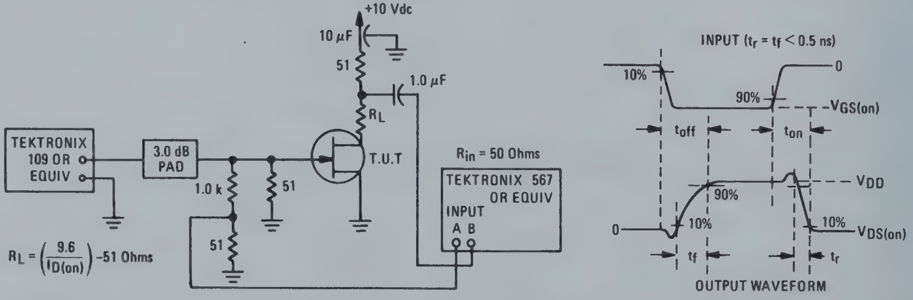
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Gate-Source Voltage	V_{GS}	40	Vdc
Forward Gate Current	$I_{G(f)}$	50	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
STYLE 4
Pin 1. Source
2. Drain
3. Gate and
Case
0.050
0.100
0.050
45°
0.036
0.046
0.028
0.048
2
1
3

CASE 22(4)
(TO-18)

FIGURE 1 SWITCHING TIMES TEST CIRCUIT


+10 Vdc
10 μF
51
1.0 μF
RL
T.U.T
TEKTRONIX
109 OR
EQUIV
3.0 dB
PAD
1.0 k
51
51
Rin = 50 Ohms
TEKTRONIX 567
OR EQUIV
INPUT
A B
RL = (9.6 / ID(on)) -51 Ohms
INPUT (tr = tf < 0.5 ns)
10%
0
90%
-VGS(on)
toff
ton
VDD
90%
0
10%
10%
VDS(on)
tf
tr
OUTPUT WAVEFORM

2N4391, 2N4392, 2N4393 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)	$V_{GS(f)}$	-	1.0	Vdc
Gate-Source Voltage (V_{DS} = 20 Vdc, I_D = 1.0 nAdc) 2N4391	V_{GS}	4.0	10	Vdc
2N4392		2.0	5.0	
2N4393		0.5	3.0	
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0)	I_{GSS}	-	0.1	nAdc
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 150°C)		-	0.2	μAdc
Drain-Cutoff Current (V_{DS} = 20 Vdc, V_{GS} = 12 Vdc) 2N4391	$I_{D(off)}$	-	0.1	nAdc
(V_{DS} = 20 Vdc, V_{GS} = 7.0 Vdc) 2N4392		-	0.1	
(V_{DS} = 20 Vdc, V_{GS} = 5.0 Vdc) 2N4393		-	0.1	
(V_{DS} = 20 Vdc, V_{GS} = 12 Vdc, T_A = 150°C) 2N4391		-	0.2	μAdc
(V_{DS} = 20 Vdc, V_{GS} = 7.0 Vdc, T_A = 150°C) 2N4392		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 5.0 Vdc, T_A = 150°C) 2N4393		-	0.2	
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current (1) (V_{DS} = 20 Vdc, V_{GS} = 0) 2N4391	I_{DSS}	50	150	mAdc
2N4392		25	75	
2N4393		5.0	30	
Drain-Source "ON" Voltage (I_D = 12 mAdc, V_{GS} = 0) 2N4391	$V_{DS(on)}$	-	0.4	Vdc
(I_D = 6.0 mAdc, V_{GS} = 0) 2N4392		-	0.4	
(I_D = 3.0 mAdc, V_{GS} = 0) 2N4393		-	0.4	
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0) 2N4391	$r_{DS(on)}$	-	30	Ohms
2N4392		-	60	
2N4393		-	100	
SMALL-SIGNAL CHARACTERISTICS				
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz) 2N4391	$r_{ds(on)}$	-	30	Ohms
2N4392		-	60	
2N4393		-	100	
Input Capacitance (V_{DS} = 20 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	14	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 12 Vdc, f = 1.0 MHz) 2N4391	C_{rss}	-	3.5	pF
(V_{DS} = 0, V_{GS} = 7.0 Vdc, f = 1.0 MHz) 2N4392		-	3.5	
(V_{DS} = 0, V_{GS} = 5.0 Vdc, f = 1.0 MHz) 2N4393		-	3.5	
SWITCHING CHARACTERISTICS				
Turn-On Time (See Figure 1) ($I_{D(on)}$ = 12 mAdc) 2N4391	t_{on}	-	15	ns
($I_{D(on)}$ = 6.0 mAdc) 2N4392		-	15	
($I_{D(on)}$ = 3.0 mAdc) 2N4393		-	15	
Rise Time (See Figure 1) ($I_{D(on)}$ = 12 mAdc) 2N4391	t_r	-	5.0	ns
($I_{D(on)}$ = 6.0 mAdc) 2N4392		-	5.0	
($I_{D(on)}$ = 3.0 mAdc) 2N4393		-	5.0	
Turn-Off Time (See Figure 1) ($V_{GS(off)}$ = 12 Vdc) 2N4391	t_{off}	-	20	ns
($V_{GS(off)}$ = 7.0 Vdc) 2N4392		-	35	
($V_{GS(off)}$ = 5.0 Vdc) 2N4393		-	50	
Fall Time (See Figure 1) ($V_{GS(off)}$ = 12 Vdc) 2N4391	t_f	-	15	ns
($V_{GS(off)}$ = 7.0 Vdc) 2N4392		-	20	
($V_{GS(off)}$ = 5.0 Vdc) 2N4393		-	30	

(1) Pulse Test: Pulse Width ≤ 100 μs, Duty Cycle ≤ 1.0%.

2N4398 PNP (SILICON)
2N4399
2N5745

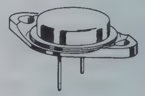
PNP SILICON HIGH-POWER TRANSISTORS

. . . designed for use in power amplifier and switching circuits; serves as direct replacements for Germanium high-power devices.

- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)}$ = 1.0 Vdc (Max) @ I_C = 15 Adc (2N4398, 2N4399)
- DC Current Gain Specified — 1.0 to 30 Adc
- Complements to NPN 2N5301, 2N5302, 2N5303

20, 30 AMPERE
POWER TRANSISTORS
PNP SILICON

40-60-80 VOLTS
200 WATTS



*MAXIMUM RATINGS

Rating	Symbol	2N4398	2N4399	2N5745	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous Peak	I_C	30 50	30 50	20 50	Adc
Base Current — Continuous Peak	I_B	← 7.5 → ← 15 →			Adc
Total Device Dissipation @ T_A = 25°C** Derate above 25°C	P_D	← 5.0 → ← 28.6 →			Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 200 → ← 1.15 →			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

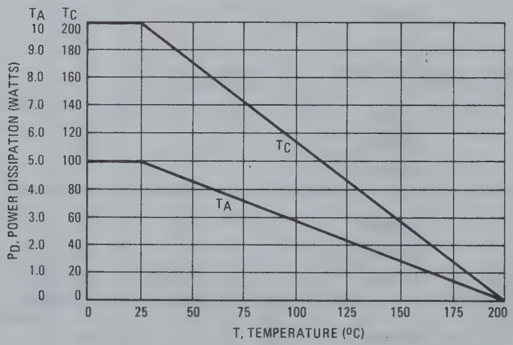
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.875	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	35	°C/W

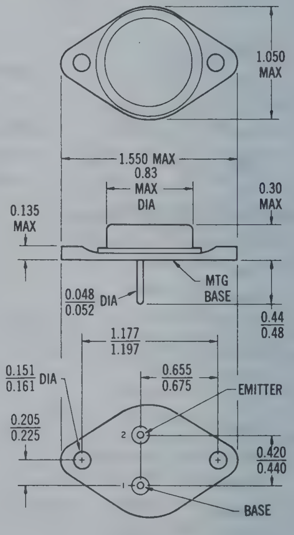
*Indicates JEDEC Registered Data

**Motorola guarantees this data in addition to JEDEC Registered Data.

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 13. All limits are applicable and must be observed.



CASE 12
(TO-3 except Pin Diameter)
(Collector Connected to Case)

To convert inches to millimeters multiply by 25.4.

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage(1) (I_C = 200 mAdc, I_B = 0)	2N4398 2N4399 2N5745	$V_{CEO(sus)}$	40 60 80	– – –	Vdc
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 40 Vdc, I_B = 0)	2N4398		–	5.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N4399		–	5.0	
(V_{CE} = 80 Vdc, I_B = 0)	2N5745		–	5.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4398		–	5.0	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4399		–	5.0	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N5745		–	5.0	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4398, 2N4399		–	10	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5745		–	10	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N4398		–	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N4399		–	1.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N5745		–	1.0	
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	–	5.0	mAdc
ON CHARACTERISTICS					
DC Current Gain(1)		h_{FE}			–
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	All Types		40	–	
(I_C = 10 Adc, V_{CE} = 2.0 Vdc)	2N5745		15	60	
(I_C = 15 Adc, V_{CE} = 2.0 Vdc)	2N4398, 2N4399		15	60	
(I_C = 20 Adc, V_{CE} = 2.0 Vdc)	2N5745		5.0	–	
(I_C = 30 Adc, V_{CE} = 4.0 Vdc)	2N4398, 2N4399		5.0	–	
Collector-Emitter Saturation Voltage(1)		$V_{CE(sat)}$			Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)	2N4398, 2N4399 2N5745		– –	0.75 1.0	
(I_C = 15 Adc, I_B = 1.5 Adc)	2N4398, 2N4399 2N5745		– –	1.0 1.5	
(I_C = 20 Adc, I_B = 2.0 Adc)	2N4398, 2N4399		–	2.0	
(I_C = 20 Adc, I_B = 4.0 Adc)	2N5745		–	2.0	
(I_C = 30 Adc, I_B = 6.0 Adc)	2N4398, 2N4399		–	4.0	
Base-Emitter Saturation Voltage(1)		$V_{BE(sat)}$			Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)**	2N4398, 2N4399 2N5745		– –	1.6 1.7	
(I_C = 15 Adc, I_B = 1.5 Adc)	2N4398, 2N4399 2N5745		– –	1.85 2.0	
(I_C = 20 Adc, I_B = 2.0 Adc)**	2N4398, 2N4399		–	2.5	
(I_C = 20 Adc, I_B = 4.0 Adc)	2N5745		–	2.5	
Base-Emitter On Voltage(1)		$V_{BE(on)}$			Vdc
(I_C = 10 Adc, V_{CE} = 2.0 Vdc)	2N5745		–	1.5	
(I_C = 15 Adc, V_{CE} = 2.0 Vdc)	2N4398, 2N4399		–	1.7	
(I_C = 20 Adc, V_{CE} = 4.0 Vdc)	2N5745		–	2.5	
(I_C = 30 Adc, V_{CE} = 4.0 Vdc)	2N4398, 2N4399		–	3.0	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product(2) (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	2N4398, 2N4399 2N5745	f_T	4.0 2.0	– –	MHz
Small-Signal Current Gain (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	40	–	–
SWITCHING CHARACTERISTICS (See Figures 2 and 3)					
Rise Time (V_{CC} = 30 Vdc, I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc)	2N4398, 2N4399 2N5745	t_r	– –	0.4 1.0	μs
Storage Time	2N4398, 2N4399 2N5745	t_s	– –	1.5 2.0	μs
Fall Time	2N4398, 2N4399 2N5745	t_f	– –	0.6 1.0	μs

*Indicates JEDEC Registered Data.

**Motorola Guarantees this Data in Addition to JEDEC Registered Data.

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

(2) f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 2 – TURN-ON TIME

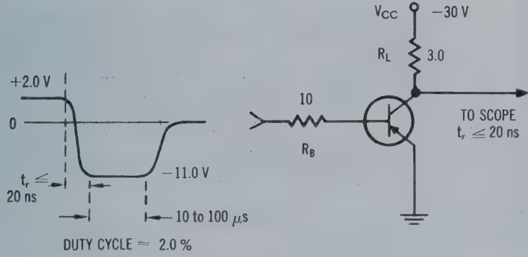
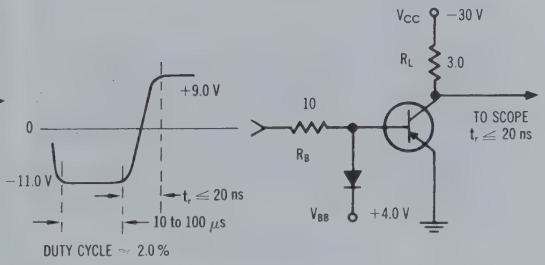


FIGURE 3 – TURN-OFF TIME



FOR CURVES OF FIGURES 5 & 6, R_B, R_L, & V_{CC} ARE VARIED
INPUT LEVELS ARE APPROXIMATELY AS SHOWN.

TYPICAL TRANSIENT CHARACTERISTICS

FIGURE 4 – CAPACITANCES

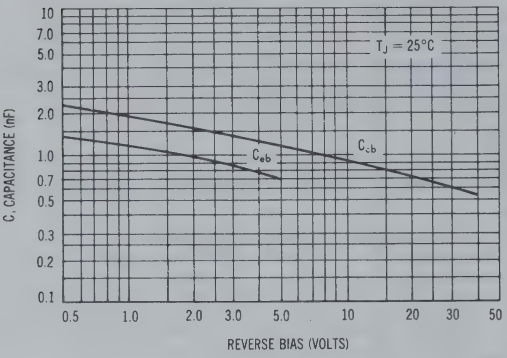


FIGURE 5 – TURN-ON TIME

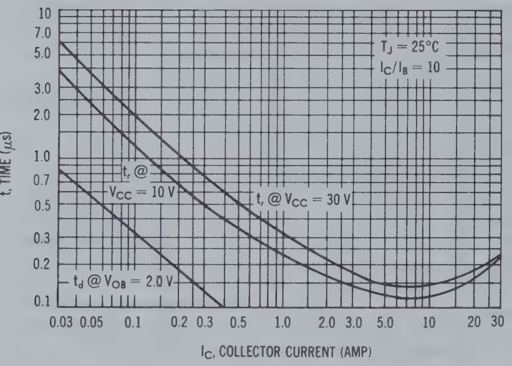
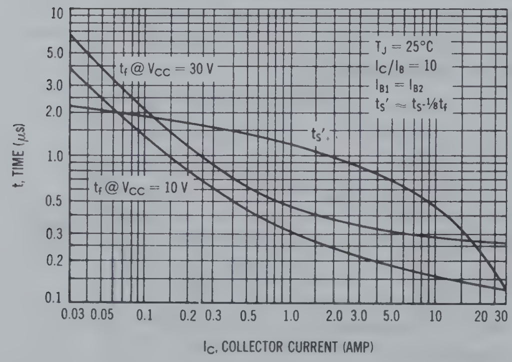


FIGURE 6 – TURN-OFF TIME



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 7 – TRANSCONDUCTANCE

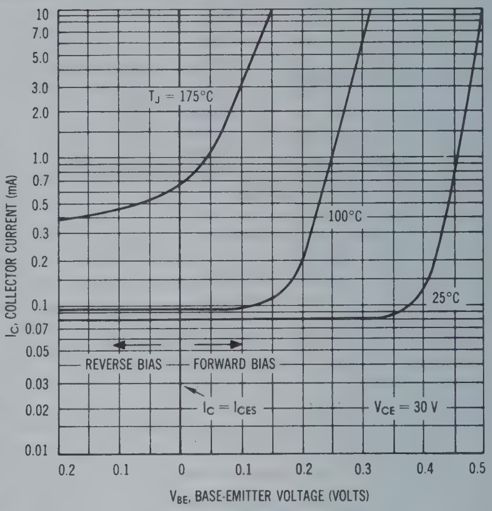
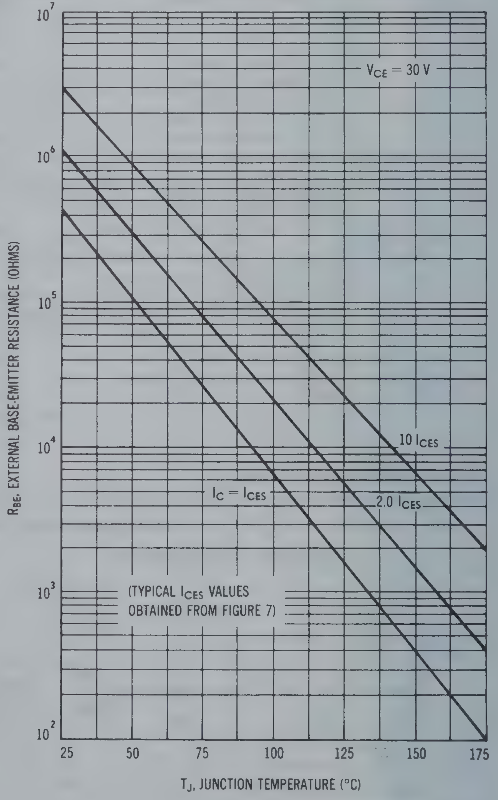


FIGURE 8 – EFFECT OF BASE-EMITTER RESISTANCE



TYPICAL "ON" REGION CHARACTERISTICS

FIGURE 9 — DC CURRENT GAIN

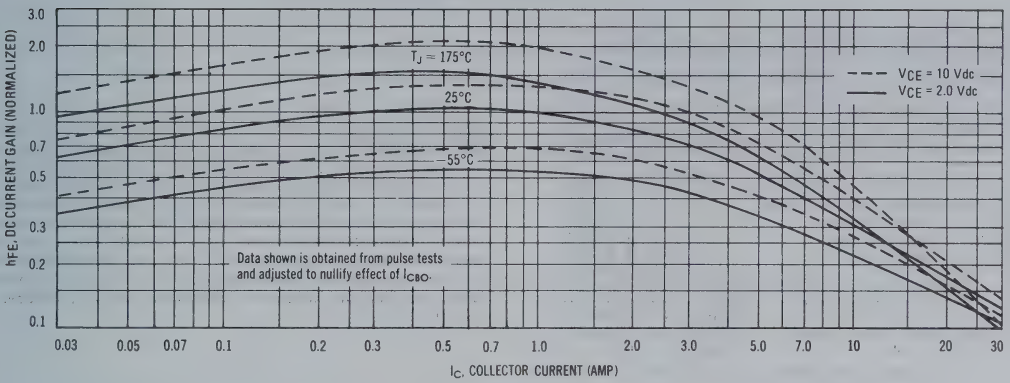


FIGURE 10 — COLLECTOR SATURATION REGION

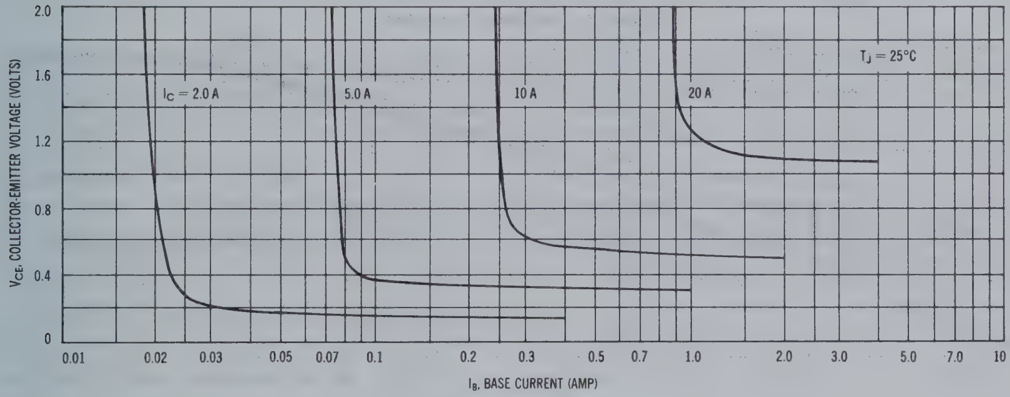


FIGURE 11 — "ON" VOLTAGES

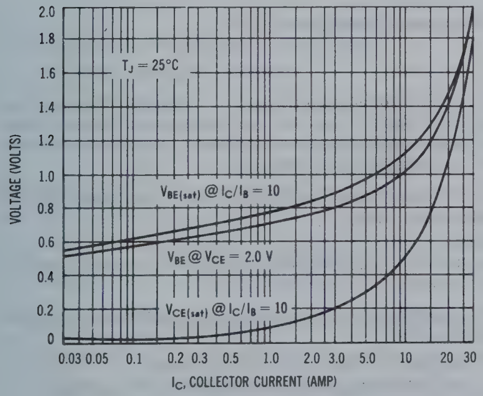
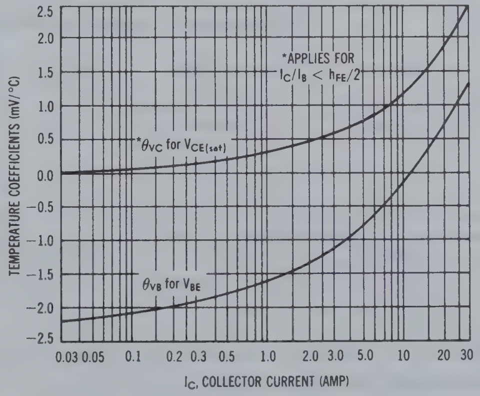
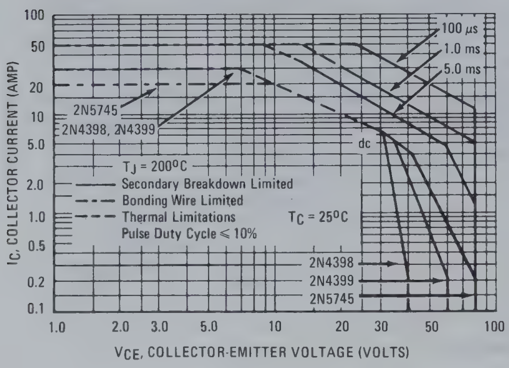


FIGURE 12 — TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

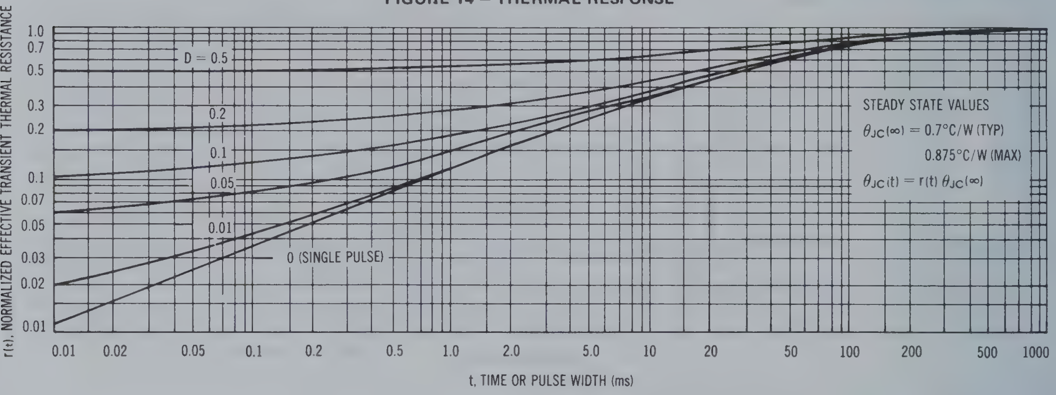
FIGURE 13 – ACTIVE-REGION SAFE OPERATING AREA



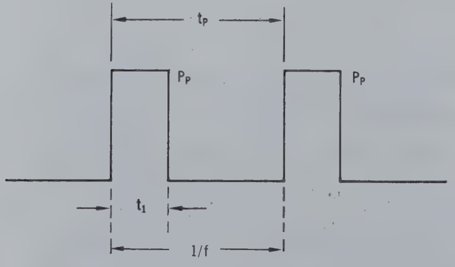
There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 13 is based on $T_{J(pk)}$ = 200°C; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leq$ 200°C. $T_{J(pk)}$ may be calculated from the data in Figure 14. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415)

FIGURE 14 – THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA



DUTY CYCLE $D = t_1 f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal reponse, the normalized effective transient thermal resistance of Figure 14 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 14 by the steady state value $\theta_{JC}(\infty)$.

Example:

The 2N4398 is dissipating 100 watts under the following conditions: t_1 = 1.0 ms, t_P = 5.0 ms. (D = 0.2)

Using Figure 14, at a pulse width of 1.0 ms and D = 0.2, the reading of r (t) is 0.28.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC}(\infty) = 0.28 \times 100 \times 0.875 = 24.5°C$$

2N4400 (SILICON)
2N4401

CASE 29(1)
(TO-92)

NPN silicon annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with PNP types 2N4402 and 2N4403. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current - Continuous	I_C	600	mAdc
Total Device Dissipation $T_A = 25^oC$ Derate above 25°C	P_D	350 2.73	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.137	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 1 mAdc, I_B = 0)			BV_{CEO}*	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)			BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)			BV_{EBO}	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 35 Vdc, $V_{EB(off)}$ = 0.4 Vdc)			I_{CEX}	—	0.1	µAdc
Base Cutoff Current (V_{CE} = 35 Vdc, $V_{EB(off)}$ = 0.4 Vdc)			I_{BL}	—	0.1	µAdc
ON CHARACTERISTICS						
DC Current Gain		15	h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc)	2N4401			20	—	
(I_C = 1 mAdc, V_{CE} = 1 Vdc)	2N4400 2N4401			20 40	— —	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N4400 2N4401			40 80	— —	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)*	2N4400 2N4401			50 100	150 300	
(I_C = 500 mAdc, V_{CE} = 2 Vdc)*	2N4400 2N4401			20 40	— —	
Collector-Emitter Saturation Voltage*		16, 17, 18	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)				—	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)				—	0.75	
Base-Emitter Saturation Voltage*		17, 18	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)				0.75	0.95	
(I_C = 500 mAdc, I_B = 50 mAdc)				—	1.2	
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N4400 2N4401		f_T	200 250	— —	MHz
Collector-Base Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz, emitter guarded)		3	C_{cb}	—	6.5	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)		3	C_{eb}	—	30	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	2N4400 2N4401	12	h_{ie}	0.5 1.0	7.5 15	k ohms
Voltage Feedback Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)		13	h_{re}	0.1	8.0	X 10^{-4}
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	2N4400 2N4401	11	h_{fe}	20 40	250 500	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)		14	h_{oe}	1.0	30	µmhos
SWITCHING CHARACTERISTICS						
Delay Time	V_{CC} = 30 Vdc, $V_{EB(off)}$ = 2 Vdc,	1, 5	t_d	—	15	ns
Rise Time	I_C = 150 mAdc, I_{B1} = 15 mAdc	1, 5, 6	t_r	—	20	ns
Storage Time	V_{CC} = 30 Vdc, I_C = 150 mAdc,	2, 7	t_s	—	225	ns
Fall Time	I_{B1} = I_{B2} = 15 mAdc	2, 8	t_f	—	30	ns

*Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2%

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — TURN-ON TIME

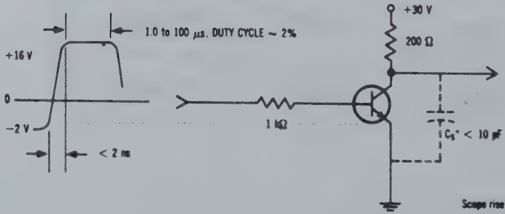
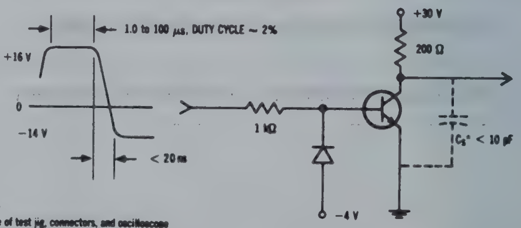


FIGURE 2 — TURN-OFF TIME



Scope rise time < 4 ns
*Total shunt capacitance of test jig, connectors, and oscilloscope

TRANSIENT CHARACTERISTICS

——— 25°C – – – 100°C

FIGURE 3 — CAPACITANCES

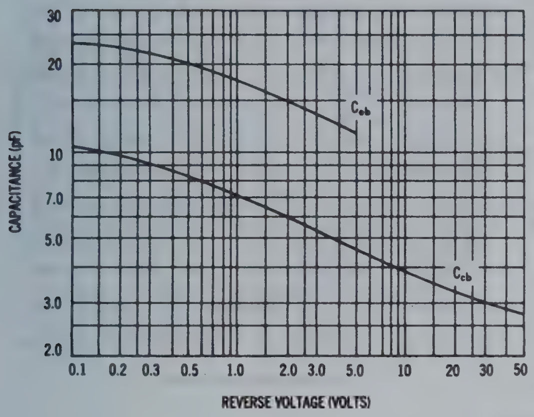


FIGURE 4 — CHARGE DATA

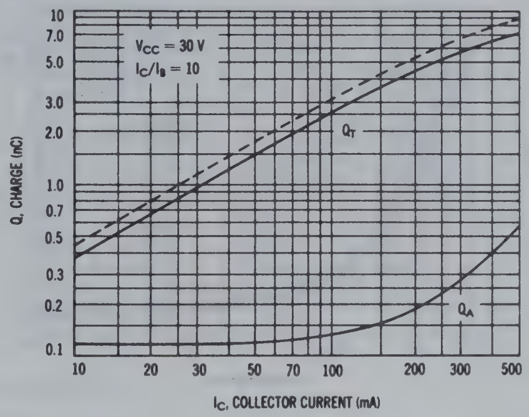


FIGURE 5 — TURN-ON TIME

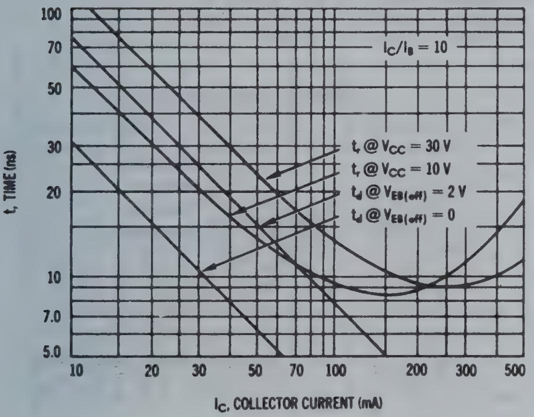


FIGURE 6 — RISE AND FALL TIMES

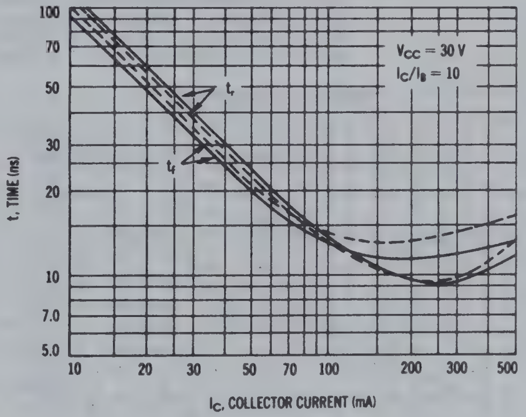


FIGURE 7 — STORAGE TIME

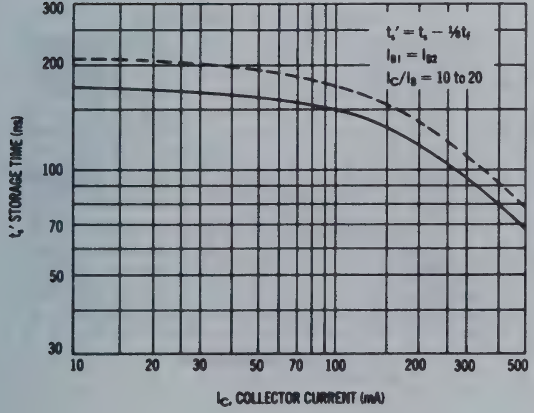
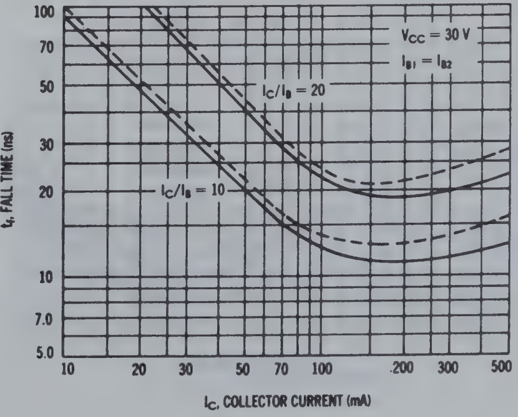


FIGURE 8 — FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 10 Vdc, T_A = 25°C

FIGURE 9 — FREQUENCY EFFECTS

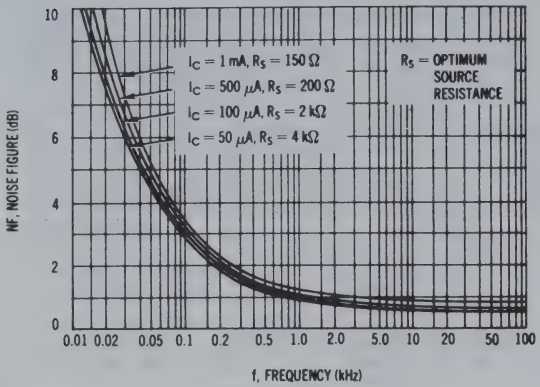
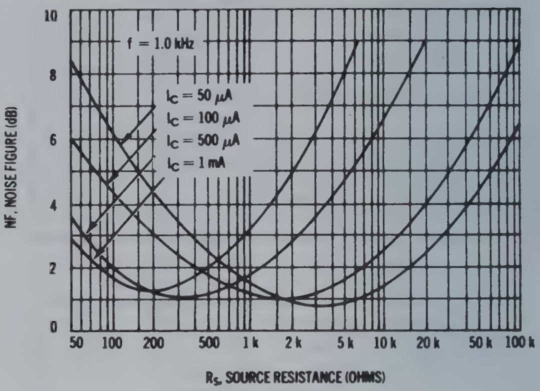


FIGURE 10 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1 kHz, T_A = 25°C

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected from both the 2N4400 and 2N4401 lines, and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 11 — CURRENT GAIN

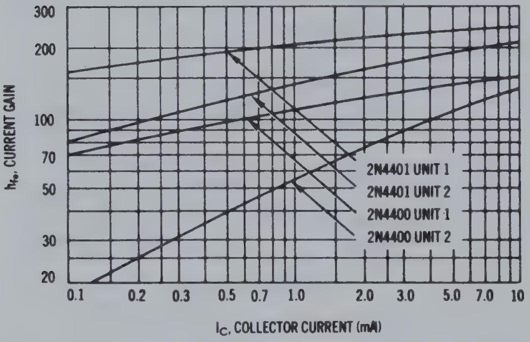


FIGURE 12 — INPUT IMPEDANCE

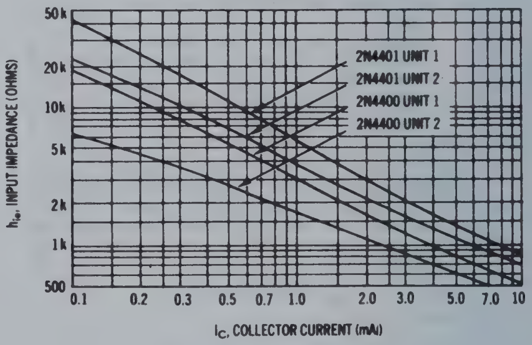


FIGURE 13 — VOLTAGE FEEDBACK RATIO

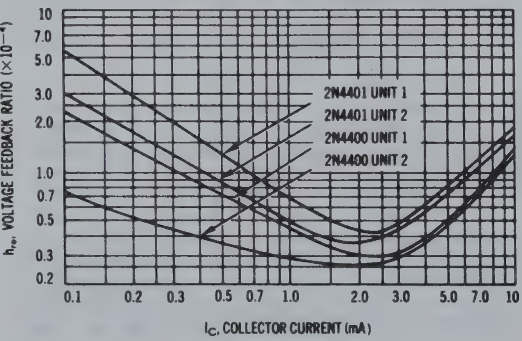
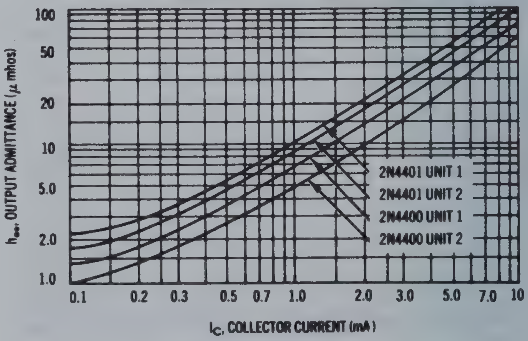


FIGURE 14 — OUTPUT ADMITTANCE



STATIC CHARACTERISTICS

FIGURE 15 — DC CURRENT GAIN

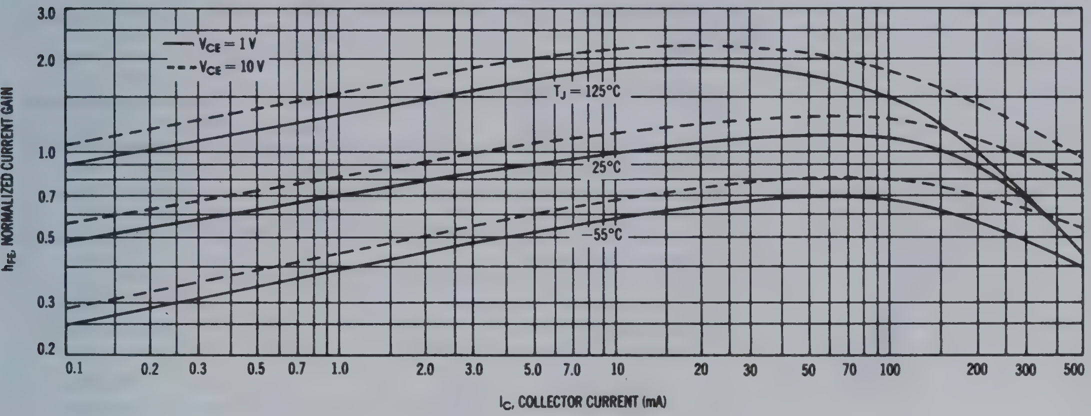


FIGURE 16 — COLLECTOR SATURATION REGION

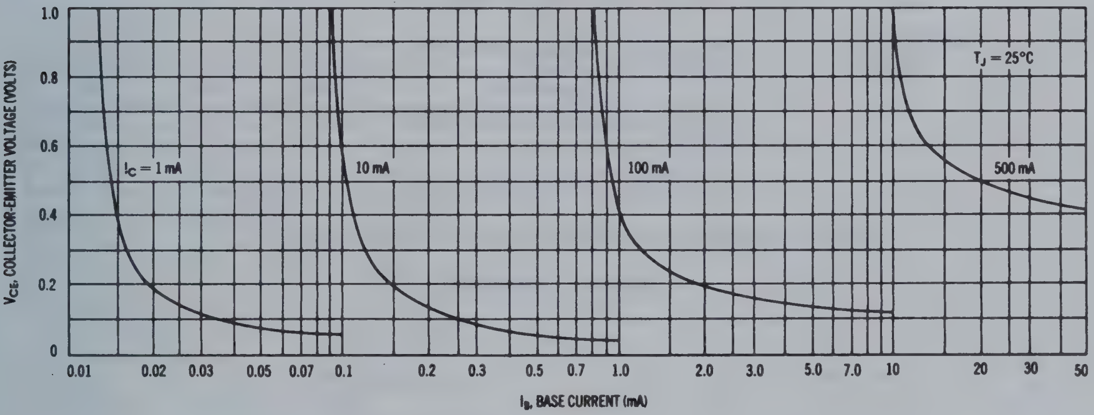


FIGURE 17 — "ON" VOLTAGES

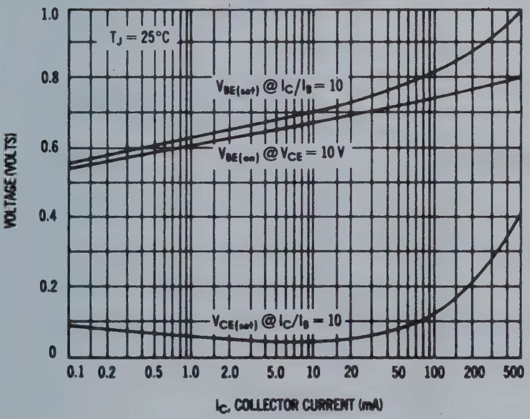
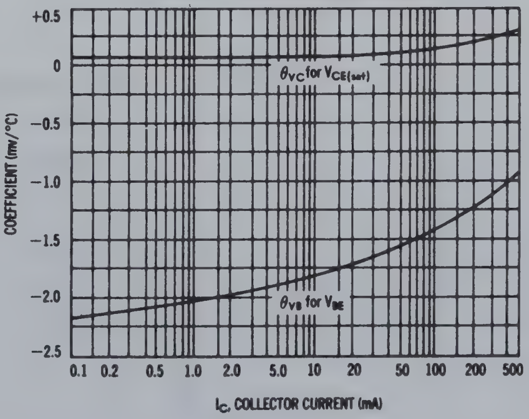


FIGURE 18 — TEMPERATURE COEFFICIENTS



2N4402 (SILICON)
2N4403

PNP silicon annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with NPN types 2N4400 and 2N4401.

CASE 29 (1)
TO-92

MAXIMUM RATINGS

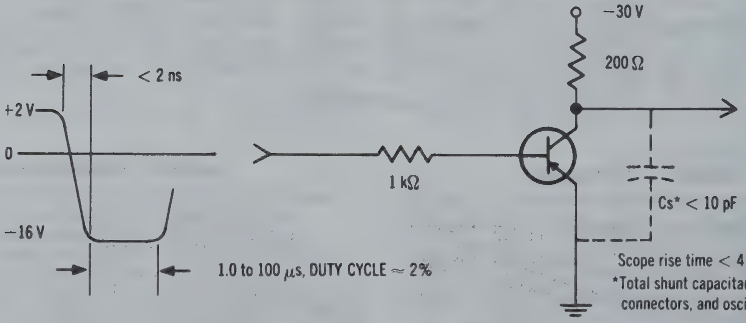
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	600	mAdc
Total Device Dissipation $T_A = 25^oC$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.137	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

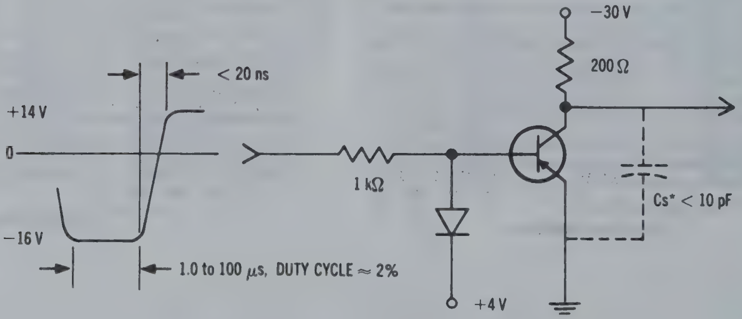
SWITCHING TIME EQUIVALENT TEST CIRCUIT

FIGURE 1 — TURN-ON TIME


−30 V
200 Ω
< 2 ns
+2 V
0
1 kΩ
−16 V
Cs* < 10 pF
1.0 to 100 µs, DUTY CYCLE ≈ 2%

Scope rise time < 4 ns
*Total shunt capacitance of test jig, connectors, and oscilloscope

FIGURE 2 — TURN-OFF TIME


−30 V
200 Ω
< 20 ns
+14 V
0
1 kΩ
Cs* < 10 pF
−16 V
1.0 to 100 µs, DUTY CYCLE ≈ 2%
+4 V

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage [1] (I_C = 1 mAdc, I_B = 0)		BV_{CEO}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 35 Vdc, $V_{BE(off)}$ = 0.4 Vdc)		I_{CEX}	—	0.1	μAdc
Base Cutoff Current (V_{CE} = 35 Vdc, $V_{BE(off)}$ = 0.4 Vdc)		I_{BL}	—	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain	15	h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc) 2N4403			30	—	
(I_C = 1 mAdc, V_{CE} = 1 Vdc) 2N4402 2N4403			30 60	— —	
(I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N4402 2N4403			50 100	— —	
(I_C = 150 mAdc, V_{CE} = 2 Vdc) [1] 2N4402 2N4403			50 100	150 300	
(I_C = 500 mAdc, V_{CE} = 2 Vdc) [1]			20	—	
Collector-Emitter Saturation Voltage [1]	16, 17, 18	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	0.75	
Base-Emitter Saturation Voltage [1]	17, 18	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			0.75	0.95	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.3	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4402 2N4403		f_T	150 200	— —	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz, emitter guarded)	3	C_{cb}	—	8.5	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz, collector guarded)	3	C_{eb}	—	30	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4402 2N4403	12	h_{ie}	750 1.5k	7.5k 15k	ohms
Voltage Feedback Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	13	h_{re}	0.1	8.0	$\times 10^{-4}$
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4402 2N4403	11	h_{fe}	30 60	250 500	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	14	h_{oe}	1.0	100	μmhos

SWITCHING CHARACTERISTICS

Delay Time	V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2 Vdc,	1, 5	t_d	—	15	ns
Rise Time	I_C = 150 mAdc, I_{B1} = 15 mAdc	1, 5, 6	t_r	—	20	ns
Storage Time	V_{CC} = 30 Vdc, I_C = 150 mAdc,	2, 7	t_s	—	225	ns
Fall Time	I_{B1} = I_{B2} = 15 mAdc	2, 8	t_f	—	30	ns

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

TRANSIENT CHARACTERISTICS

——— 25°C — — — 100°C

FIGURE 3 — CAPACITANCES

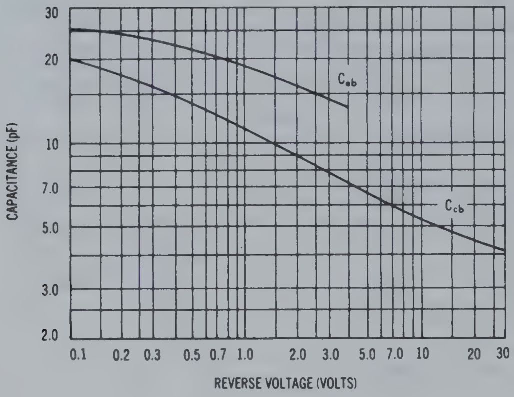


FIGURE 4 — CHARGE DATA

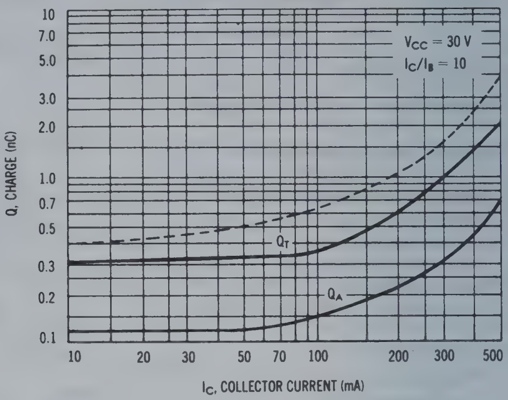


FIGURE 5 — TURN-ON TIME

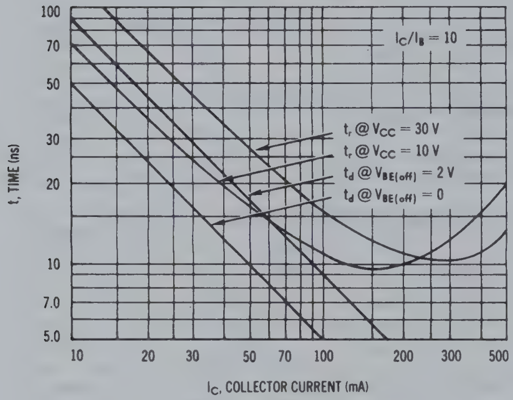


FIGURE 6 — RISE TIME

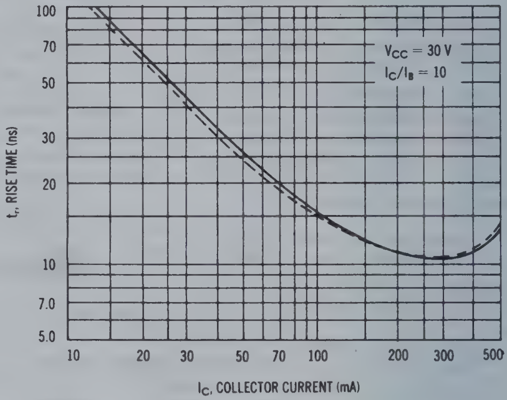


FIGURE 7 — STORAGE TIME

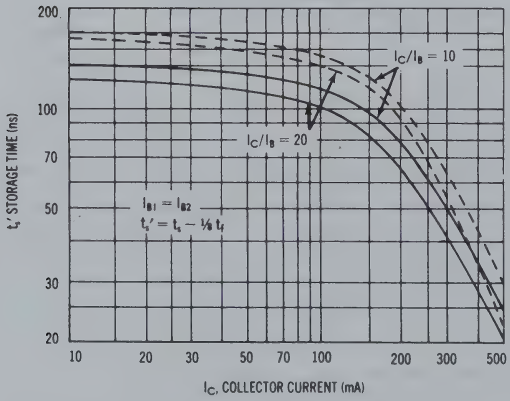
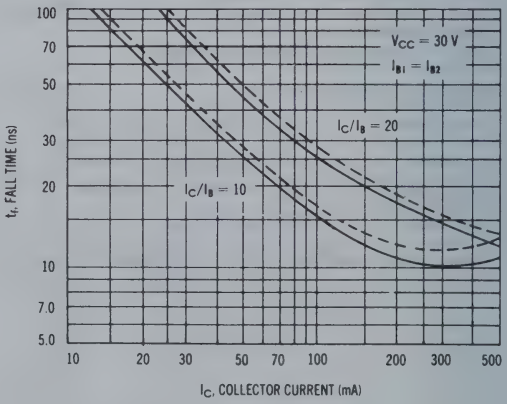


FIGURE 8 — FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 10 Vdc, T_A = 25°C

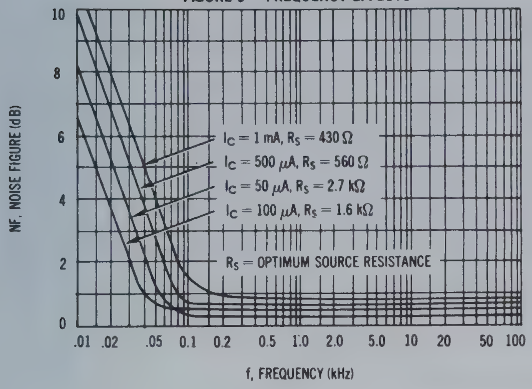


FIGURE 9 — FREQUENCY EFFECTS

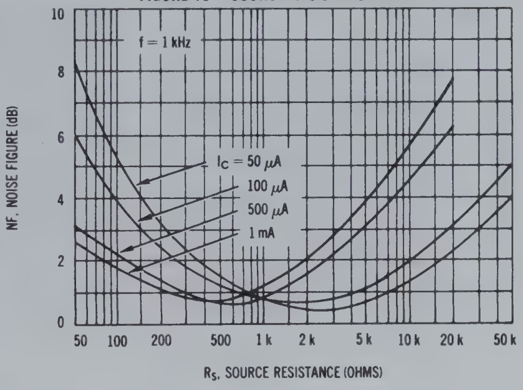


FIGURE 10 — SOURCE RESISTANCE EFFECTS

h PARAMETERS

V_{CE} = 10 Vdc, f = 1 kHz, T_A = 25°C

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected from both the 2N4402 and 2N4403 lines, and the same units were used to develop the correspondingly-numbered curves on each graph.

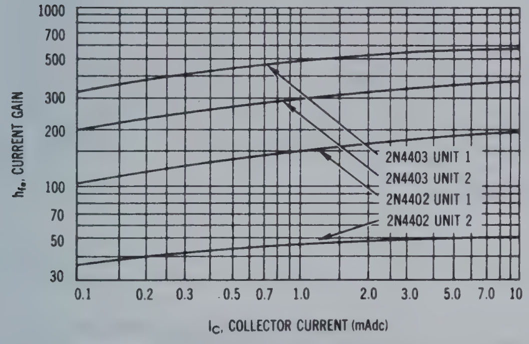


FIGURE 11 — CURRENT GAIN

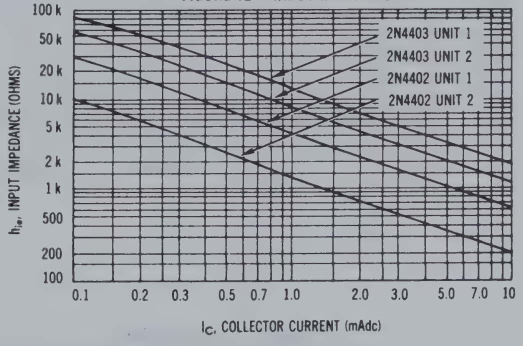


FIGURE 12 — INPUT IMPEDANCE

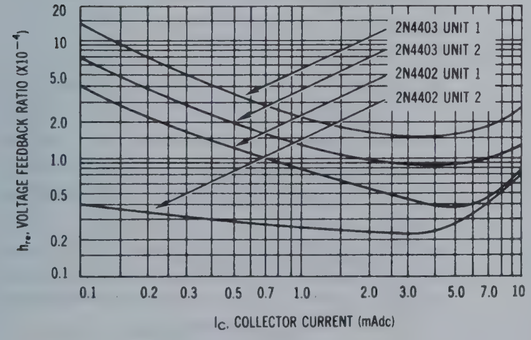


FIGURE 13 — VOLTAGE FEEDBACK RATIO

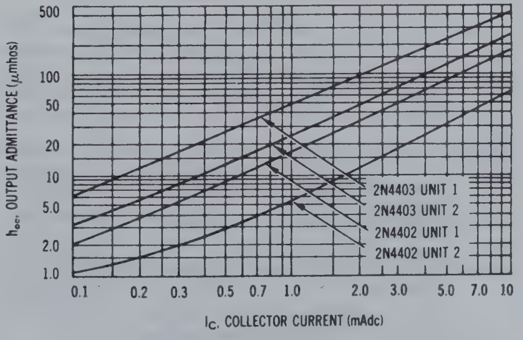


FIGURE 14 — OUTPUT ADMITTANCE

STATIC CHARACTERISTICS

FIGURE 15 — DC CURRENT GAIN

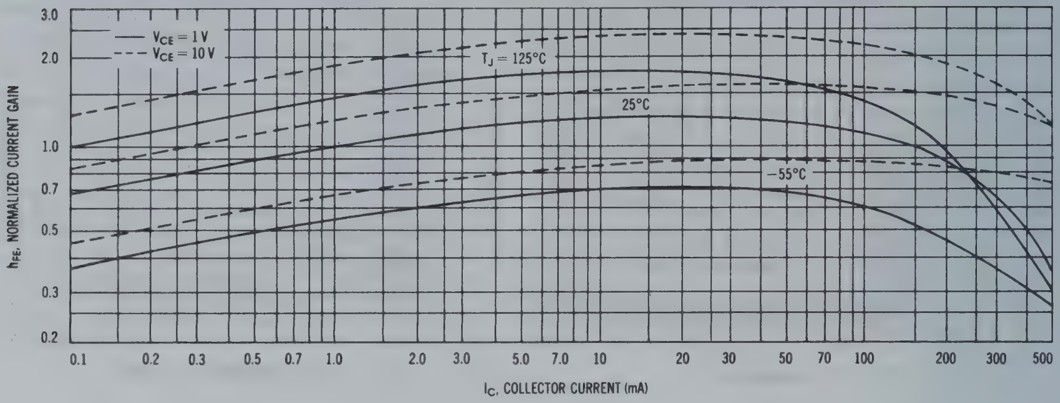


FIGURE 16 — COLLECTOR SATURATION REGION

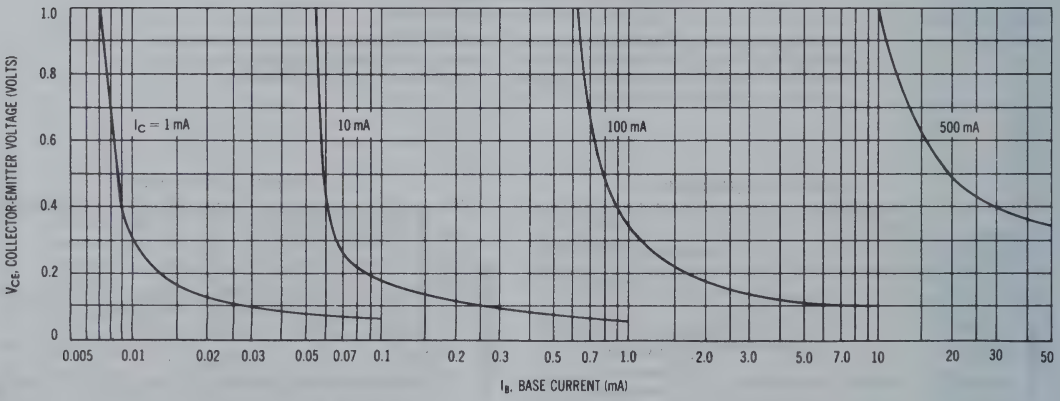


FIGURE 17 — "ON" VOLTAGE

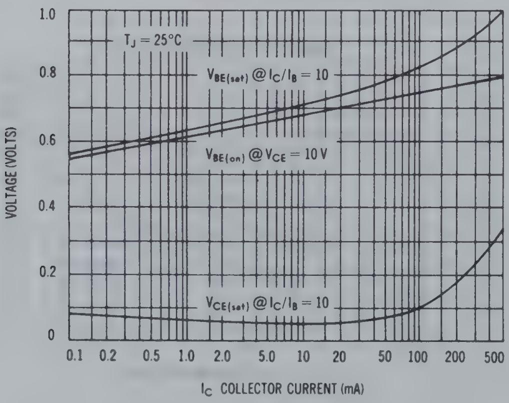
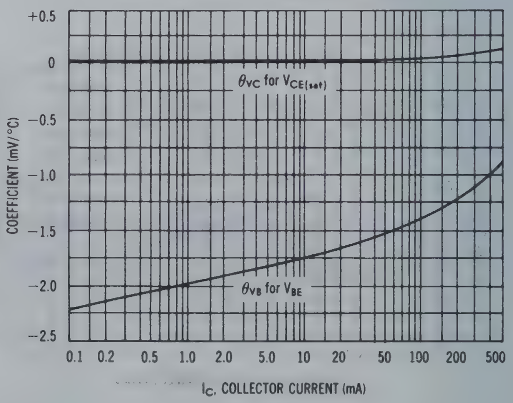
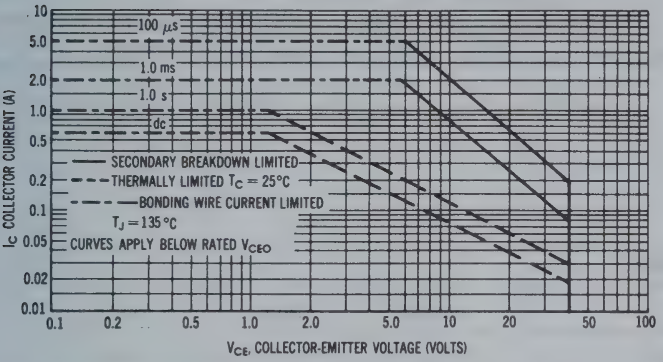


FIGURE 18 — TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

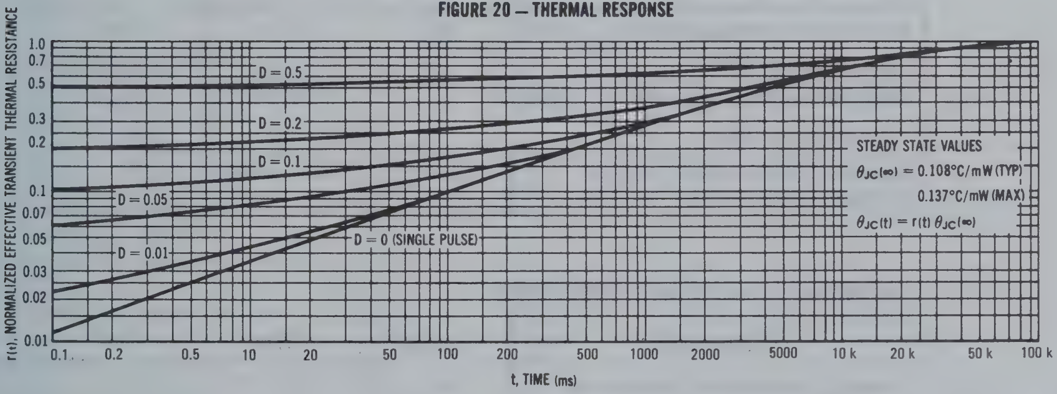
FIGURE 19 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

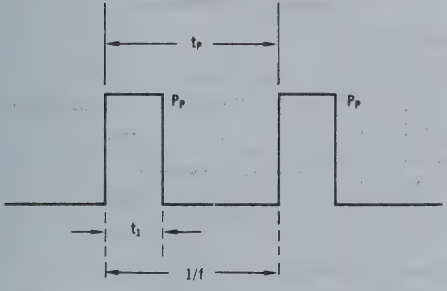
The data of Figure 19 is based upon $T_{J(pk)} = 135°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 135°C$. $T_{J(pk)}$ may be calculated from the data in Figure 20. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by the secondary breakdown.

FIGURE 20 — THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 20 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 20 by the steady state value $\theta_{JC}(\infty)$.

Example:

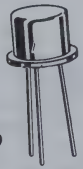
The 2N4402 is dissipating 2.0 watts under the following conditions: $t_1 = 1.0$ ms, $t_P = 5.0$ ms. (D = 0.2)

Using Figure 20, at a pulse width of 1.0 ms and D = 0.2, the reading of r (t) is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC}(\infty) = 0.27 \times 2000 \times 0.137 = 74.0°C$$

2N4404 (SILICON)
2N4405



CASE 79
(TO-39)

PNP silicon annular transistors designed for general-purpose amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.25 7.15	Watts mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	7.0 40	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	25	°C/W
Thermal Resistance, Junction to Ambient (Lead Length 1/4")	θ_{JA}	140	°C/W

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 – TURN-ON

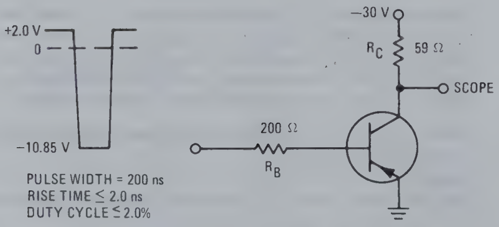
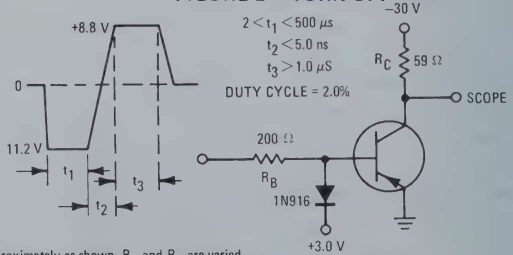

+2.0 V
0
−10.85 V
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 2.0%
−30 V
R_C
59 Ω
SCOPE
200 Ω
R_B

FIGURE 2 – TURN-OFF


−30 V
+8.8 V
0
11.2 V
t_1
t_2
t_3
$2 < t_1 < 500\ \mu s$
$t_2 < 5.0$ ns
$t_3 > 1.0\ \mu S$
DUTY CYCLE = 2.0%
R_C
59 Ω
SCOPE
200 Ω
R_B
1N916
+3.0 V

To obtain data for curves, voltage levels are approximately as shown, R_B and R_C are varied.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage[1] (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	80	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	-	25	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	25	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N4404	h_{FE}	30	-	-
	2N4405		75	-	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N4404		40	-	
	2N4405		100	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)[1]	2N4404		40	120	
	2N4405		100	300	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)[1]	2N4404		15	-	
	2N4405		25	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	-	0.15	Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)[1]			-	0.2	
(I_C = 500 mAdc, I_B = 50 mAdc)[1]			-	0.5	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{BE(sat)}$	-	0.8	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)[1]			0.85	1.2	
Base-Emitter On Voltage* (I_C = 150 mAdc, V_{CE} = 1.0 Vdc)		$V_{BE(on)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	200	600	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{cb}	-	10	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)		C_{eb}	-	75	pF
SWITCHING CHARACTERISTICS					
Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc) (Figure 1)	t_d	-	15	ns
Rise Time		t_r	-	25	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc) (Figure 2)	t_s	-	175	ns
Fall Time		t_f	-	35	ns

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

TRANSIENT CHARACTERISTICS

——— 25°C   – – – 100°C

FIGURE 3 – CAPACITANCES

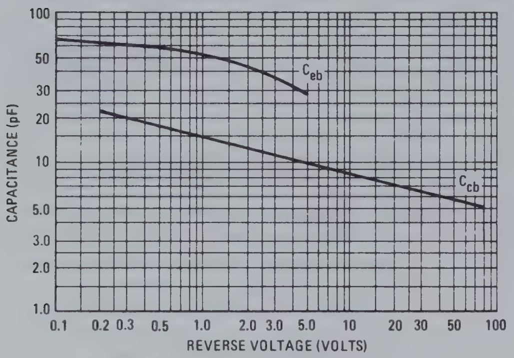


FIGURE 4 – CHARGE DATA

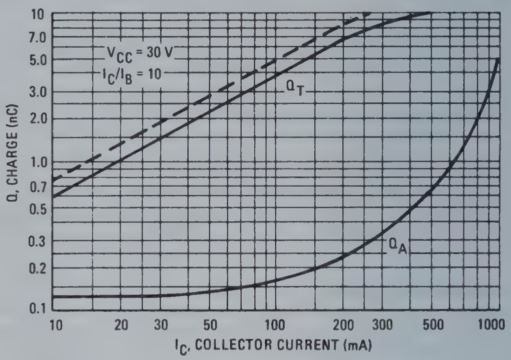


FIGURE 5 – DELAY TIME

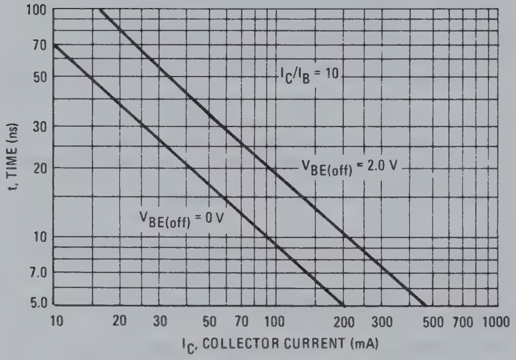


FIGURE 6 – RISE TIME

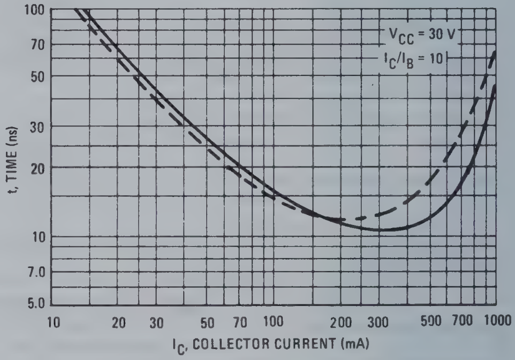


FIGURE 7 – STORAGE TIME

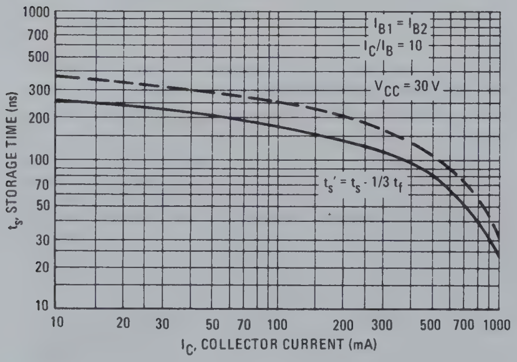
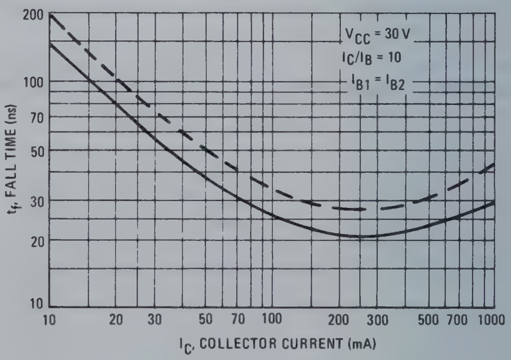


FIGURE 8 – FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 10 Vdc, T_A = 25°C

FIGURE 9 — FREQUENCY EFFECTS

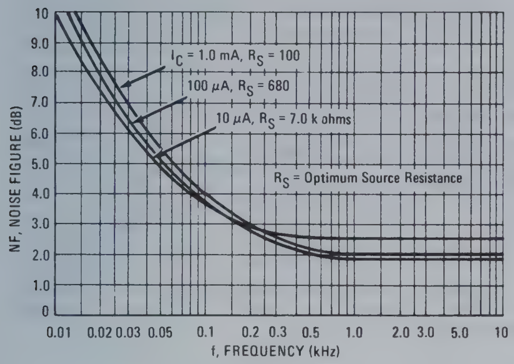
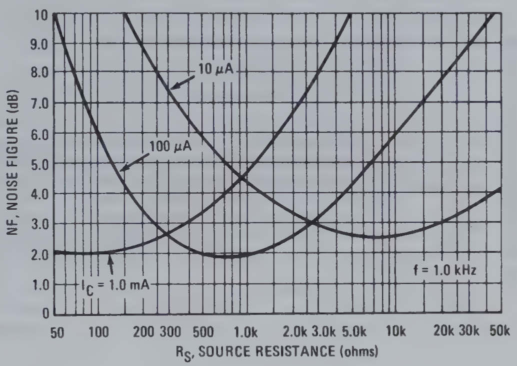


FIGURE 10 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C

This group of graphs illustrates the relationship of the "h" parameters for this series of transistors. To obtain these curves, 4 units were selected and identified by number — the same units were used to develop curves on each graph.

FIGURE 11 — CURRENT GAIN

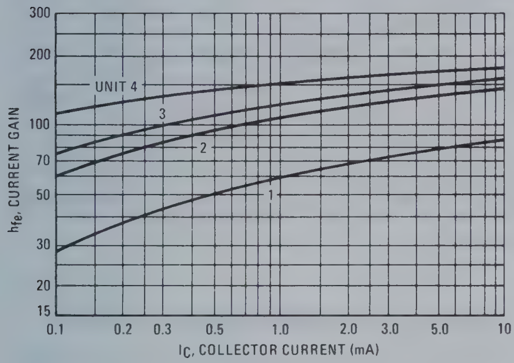


FIGURE 12 — INPUT IMPEDANCE

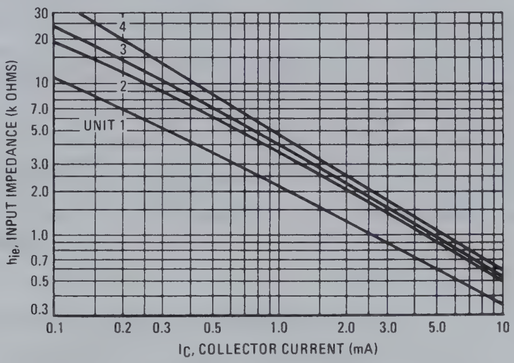


FIGURE 13 — VOLTAGE FEEDBACK RATIO

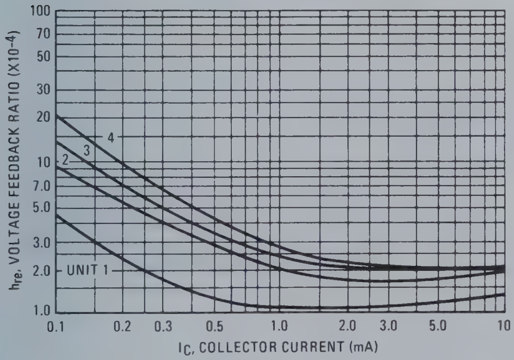
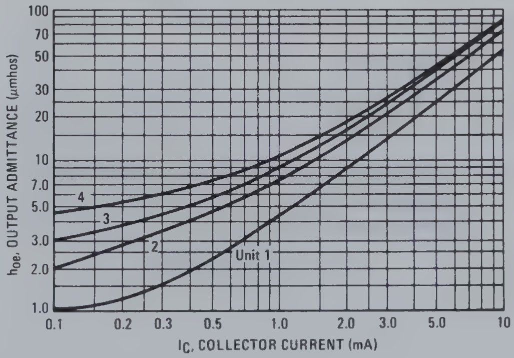


FIGURE 14 — OUTPUT ADMITTANCE



STATIC CHARACTERISTICS

FIGURE 15 – DC CURRENT GAIN

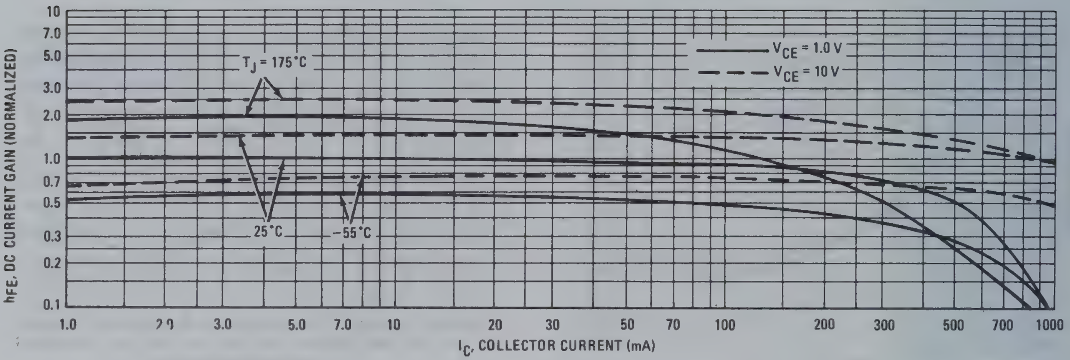


FIGURE 16 – COLLECTOR SATURATION REGION

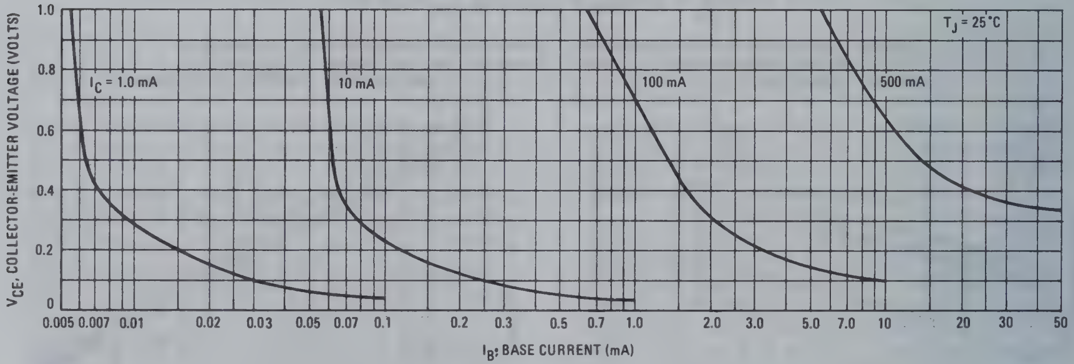


FIGURE 17 – "ON" VOLTAGES

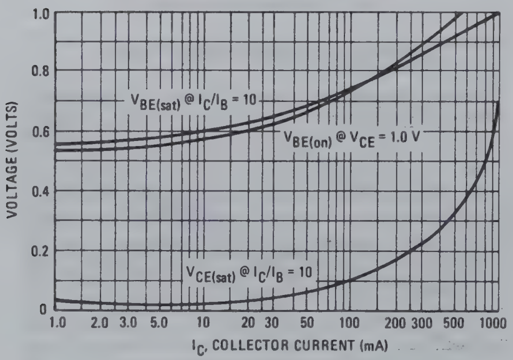
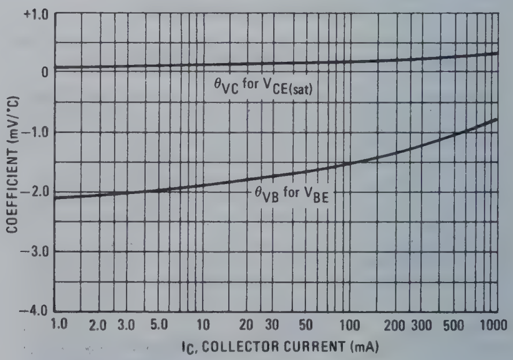
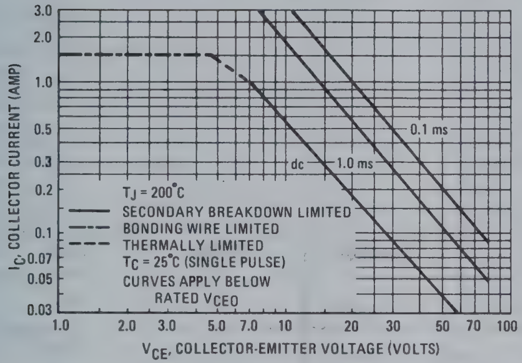


FIGURE 18 – TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

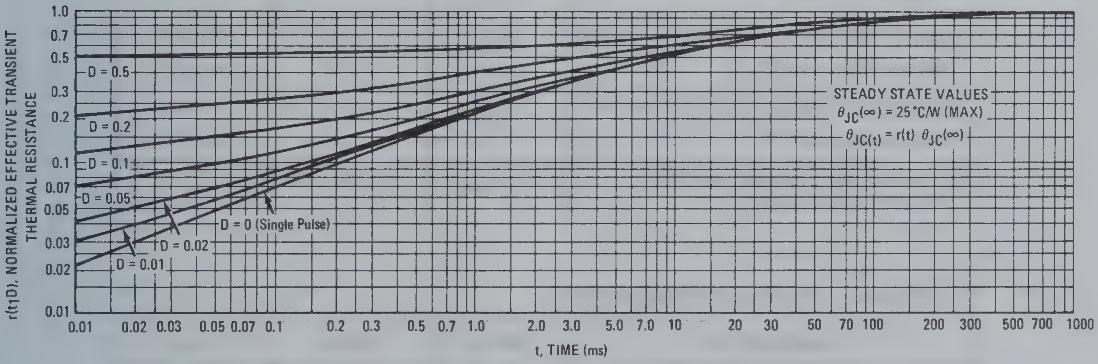
FIGURE 19 — SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

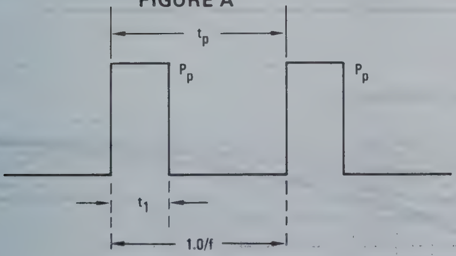
The data of Figure 19 is based upon $T_{J(pk)} = 200°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 20. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

FIGURE 20 — THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 f = \frac{t_1}{t_p}$

PEAK PULSE POWER = P_p

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 20 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 20 by the steady state value $\theta_{JC}(\infty)$.

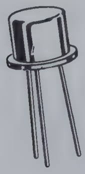
Example:

If the 2N4404 is dissipating 8.0 watts peak under the following conditions: $t_1 = 1.0$ ms, $t_p = 5.0$ ms, (D = 0.2), find ΔT.

Using Figure 20 at a pulse width of 1.0 ms and D = 0.2, the reading of $r(t_1D)$ is 0.4.

The peak rise in junction temperature above case temperature is, therefore, $\Delta T = r(t_1D) \times P_p \times \theta_{JC}(\infty) = 0.4 \times 8.0 \times 25 = 80°C$.

2N4406 (SILICON)
2N4407



CASE 79
(TO-39)

PNP silicon annular transistors designed for general-purpose amplifier and switching applications.

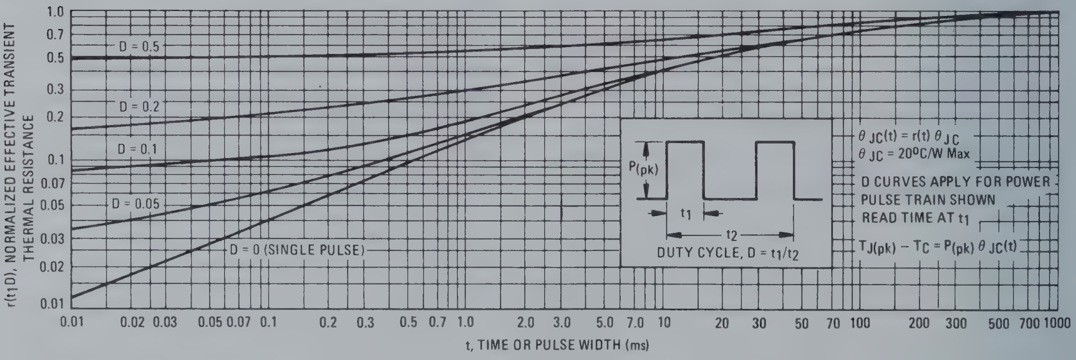
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	2.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.25 7.15	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	8.75 50	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	20	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	140	°C/W

FIGURE 1 - THERMAL RESPONSE



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage[1] (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	80	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	-	25	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	25	nAdc
ON CHARACTERISTICS					
DC Current Gain[1]		h_{FE}			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N4406 2N4407		30 80	- -	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N4406 2N4407		25 75	100 225	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	2N4406 2N4407		20 35	- -	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	2N4406 2N4407		10 15	- -	
(I_C = 1.5 Adc, V_{CE} = 5.0 Vdc)	2N4406, 2N4407		10	-	
Collector-Emitter Saturation Voltage[1]		$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			-	0.2	
(I_C = 500 mAdc, I_B = 50 mAdc)			-	0.4	
(I_C = 1.0 Adc, I_B = 100 mAdc)			-	0.7	
(I_C = 1.5 Adc, I_B = 150 mAdc)			-	1.5	
Base-Emitter Saturation Voltage[1]		$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			-	0.9	
(I_C = 1.0 Adc, I_B = 100 mAdc)			0.9	1.3	
(I_C = 1.5 Adc, I_B = 150 mAdc)			-	1.5	
Base-Emitter On Voltage[1] (I_C = 500 mAdc, V_{CE} = 1.0 Vdc)		$V_{BE(on)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	150	750	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{cb}	-	15	pF
Collector-Emitter Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)		C_{eb}	-	160	pF
SWITCHING CHARACTERISTICS					
Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 1.0 Adc, I_{B1} = 100 mAdc) (Figure 11)	t_d	-	15	ns
Rise Time		t_r	-	60	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 1.0 Adc, I_{B1} = I_{B2} = 100 mAdc) (Figure 12)	t_s	-	175	ns
Fall Time		t_f	-	50	ns

[1] Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

STATIC CHARACTERISTICS

FIGURE 2 - DC CURRENT GAIN

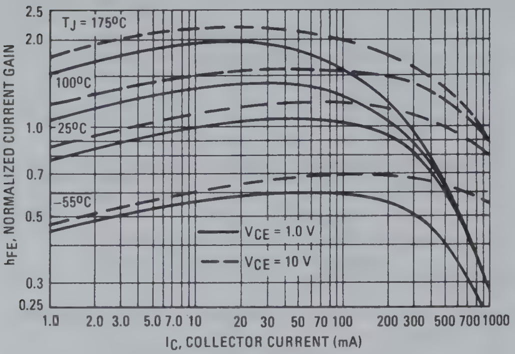


FIGURE 3 - COLLECTOR SATURATION REGION

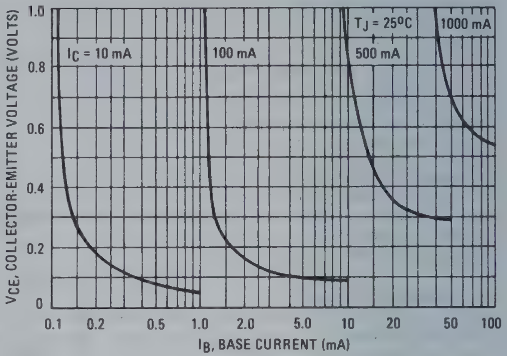


FIGURE 4 - "ON" VOLTAGES

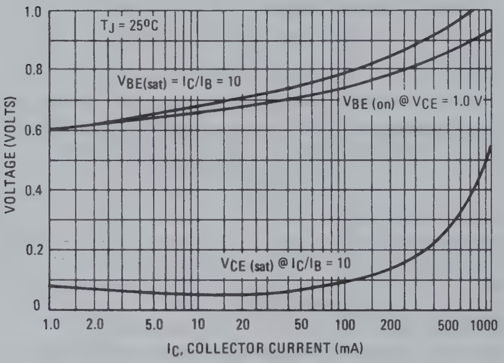


FIGURE 5 - TEMPERATURE COEFFICIENTS

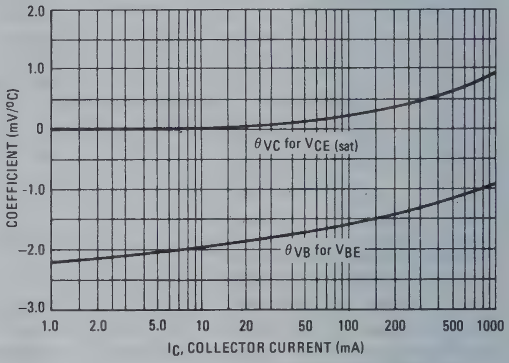
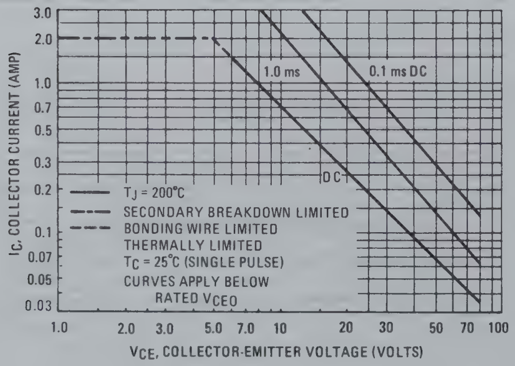


FIGURE 6 - SAFE OPERATING AREA



The safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 6 is based upon $T_{J(pk)} = 200°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leqq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 1. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

TRANSIENT CHARACTERISTICS

—— 25°C – – – 100°C

FIGURE 7 - CAPACITANCES

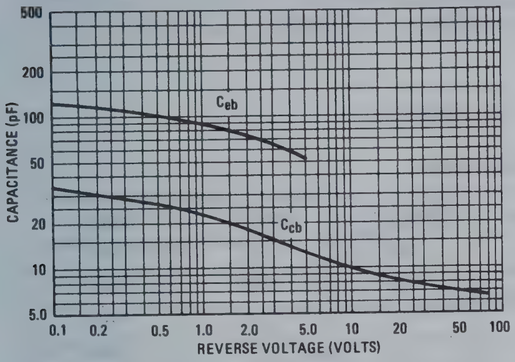


FIGURE 8 - CHARGE DATA

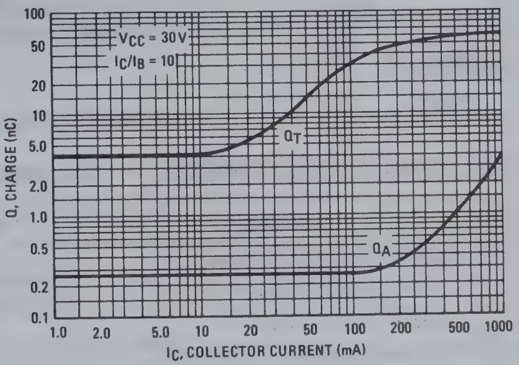


FIGURE 9 - TURN-ON TIME

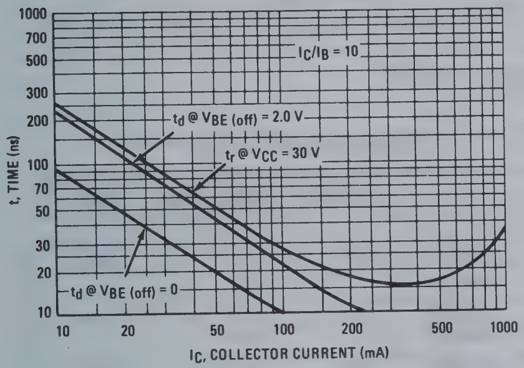
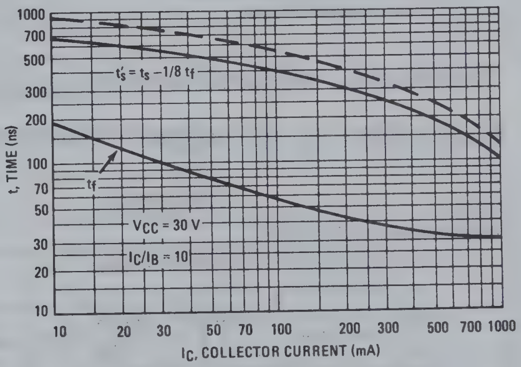
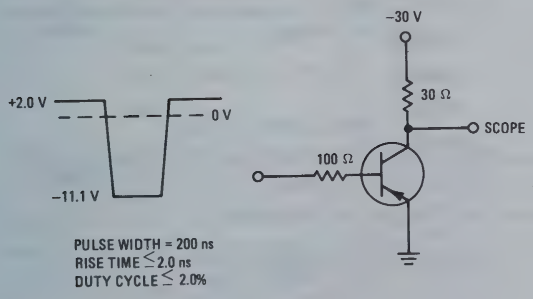


FIGURE 10 - TURN-OFF TIME



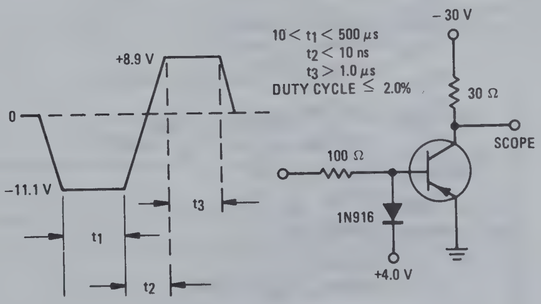
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 11 - TURN-ON TIME


+2.0 V
0 V
−11.1 V
−30 V
30 Ω
SCOPE
100 Ω

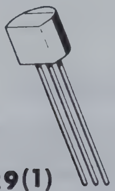
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 2.0%

FIGURE 12 - TURN-OFF TIME


+8.9 V
0
−11.1 V
t1
t2
t3
−30 V
30 Ω
SCOPE
100 Ω
1N916
+4.0 V

10 < t_1 < 500 μs
t_2 < 10 ns
t_3 > 1.0 μs
DUTY CYCLE ≤ 2.0%

2N4409 (SILICON)
2N4410



CASE 29(1)
(TO-92)

NPN silicon epitaxial transistors designed for driving neon display tubes. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	2N4409	2N4410	Unit
Collector-Emitter Voltage	V_{CEO}	50	80	Vdc
Collector-Base Voltage	V_{CB}	80	120	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Collector Current - Continuous	I_C	250		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL RESISTANCE: $\theta_{JA} = 0.357$°C/mW

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	2N4409 2N4410	BV_{CEO}	50 80	— —	Vdc
Collector-Emitter Breakdown Voltage (I_C = 500 μAdc, V_{BB} = 5 Vdc, R_{BE} = 8.2 k ohms)	2N4409 2N4410	BV_{CEX}	80 120	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_C = 0)	2N4409 2N4410	BV_{CBO}	80 120	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 100°C) (V_{CB} = 100 Vdc, I_E = 0) (V_{CB} = 100 Vdc, I_E = 0, T_A = 100°C)	 2N4409 2N4409 2N4410 2N4410	I_{CBO}	 — — — —	 0.01 1.0 0.01 1.0	μAdc
Emitter Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)		I_{EBO}	—	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc)		h_{FE}	 60 60	 400 —	—
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)		$V_{CE(sat)}$	—	0.2	Vdc
Base-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)		$V_{BE(sat)}$	—	0.8	Vdc
Base-Emitter On Voltage (I_C = 1 mAdc, V_{CE} = 5 Vdc)		$V_{BE(on)}$	—	0.8	Vdc

DYNAMIC CHARACTERISTICS

Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	300	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz, emitter guarded)	C_{cb}	—	12	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)	C_{eb}	—	50	pF

TYPICAL DC CHARACTERISTICS

FIGURE 1 — CURRENT GAIN

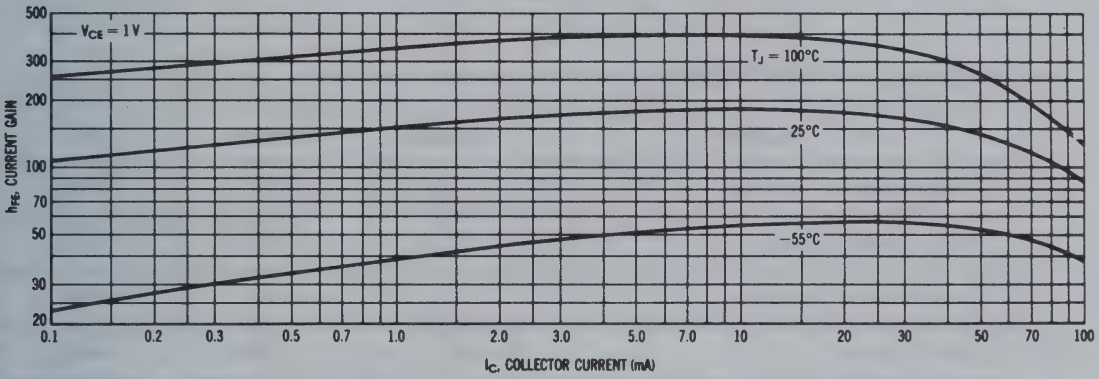


FIGURE 2 — SATURATION VOLTAGES

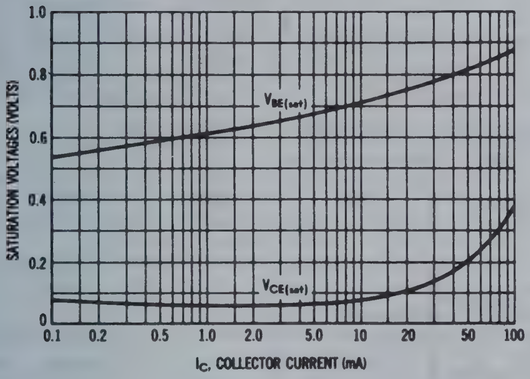


FIGURE 3 — TEMPERATURE COEFFICIENTS

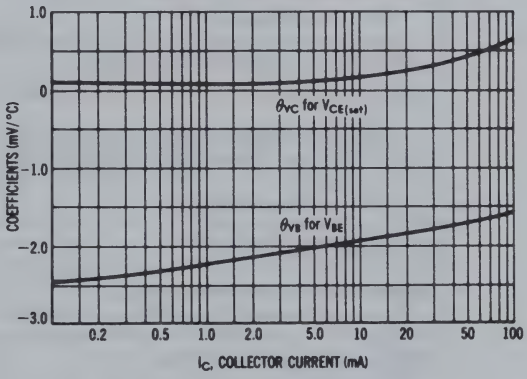


FIGURE 4 — CUTOFF CURRENT

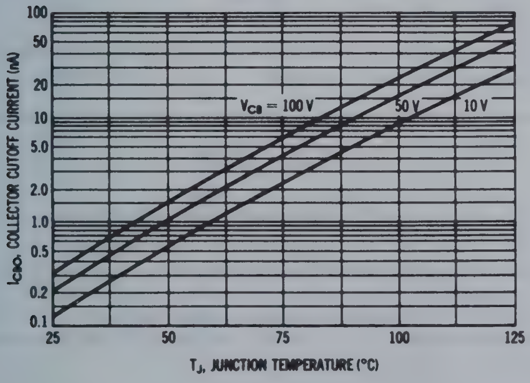
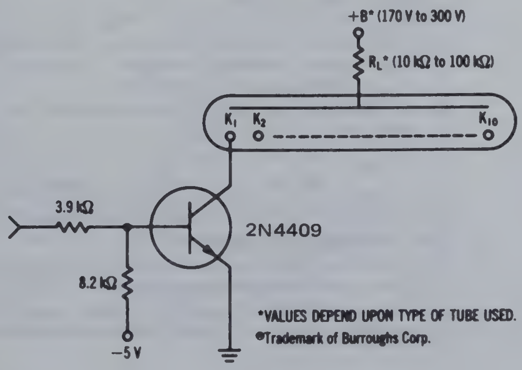
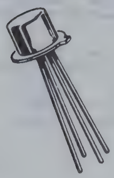


FIGURE 5 — TYPICAL NIXIE® DRIVER APPLICATION



*VALUES DEPEND UPON TYPE OF TUBE USED.
®Trademark of Burroughs Corp.

2N4416 (SILICON)



CASE 20 (1)
(TO-72)

Silicon N-channel junction field-effect transistor designed for VHF/UHF amplifier applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A @ 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

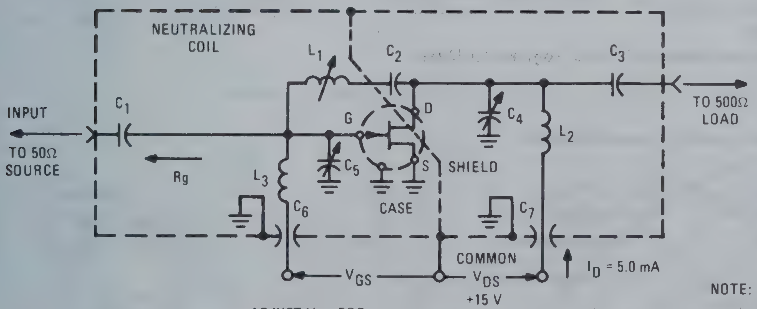
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = -1.0 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	30	-	Vdc
Gate-Source Cutoff Voltage (I_D = 1.0 nAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	-	6.0	Vdc
Gate-Source Voltage (I_D = 0.5 mAdc, V_{DS} = 15 Vdc)	V_{GS}	1.0	5.5	Vdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)	$V_{GS(f)}$	-	1.0	Vdc
Gate Reverse Current (V_{GS} = -20 Vdc, V_{DS} = 0) (V_{GS} = -20 Vdc, V_{DS} = 0, T_A = +150°C)	I_{GSS}	- -	100 200	pAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	5.0	15	mAdc

SMALL-SIGNAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Forward Transfer Admittance (1) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{fs}\|$	4500	7500	μmhos
Real Part of Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)	$RE(y_{fs})$	4000	-	μmhos
Real Part of Input Conductance	$RE(y_{is})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	100	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	1000	
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$	-	50	μmhos
Real Part of Output Conductance	$RE(y_{os})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	75	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	100	
Imaginary Part of Input Susceptance	$IM(y_{is})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	2500	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	10, 000	
Imaginary Part of Output Susceptance	$IM(y_{os})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	1000	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	4000	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	4.0	pF
Common-Source Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{osp}	-	2.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	0.8	pF
Common-Source Spot Noise Figure (Figure 1)	NF			dB
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, $R_g \approx$ 1000 ohms, f = 100 MHz)		-	2.0	
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, $R_g \approx$ 1000 ohms, f = 400 MHz)		-	4.0	
Small-Signal Power Gain (Figure 1)	G_{ps}			dB
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, f = 100 MHz)		18	-	
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, f = 400 MHz)		10	-	

(1) Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

FIGURE 1 – 100 MHz & 400 MHz NEUTRALIZED AMPLIFIER



ADJUST V_{GS} FOR
I_D = 5.0 mA
V_{GS} < 0 VOLTS

Reference Designation	VALUE	
	100 MHZ	400 MHz
C_1	7.0 pF	1.8 pF
C_2	1000 pF	17 pF
C_3	3.0 pF	1.0 pF
C_4	1-12 pF	0.8-8.0 pF
C_5	1-12 pF	0.8-8.0 pF
C_6	0.0015 μF	0.001 μF
C_7	0.0015 μF	0.001 μF
L_1	3.0 μH*	0.2 μH**
L_2	0.15 μH*	0.03 μH**
L_3	0.14 μH*	0.022 μH**

NOTE: The noise source is a hot-cold body (AIL type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

*	L_1	17 turns, (approx. – depends upon circuit layout) AWG #28 enameled copper wire, close wound on 9/32" ceramic coil form. Tuning provided by a powdered iron slug.	**	L_1	6 turns, (approx. – depends upon circuit layout) AWG #24 enameled copper wire, close wound on 7/32" ceramic coil form. Tuning provided by an aluminum slug.
	L_2	4 1/2 turns, AWG #18 enameled copper wire, 5/16" long, 3/8" I.D. (AIR CORE).		L_2	1 turn, AWG #16 enameled copper wire, 3/8" I.D. (AIR CORE).
	L_3	3 1/2 turns, AWG #18 enameled copper wire, 1/4" long, 3/8" I.D. (AIR CORE).		L_3	1/2 turn, AWG #16 enameled copper wire, 1/4" I.D. (AIR CORE).

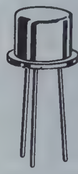
2N4427 (SILICON)

NPN SILICON RF POWER TRANSISTOR

. . . designed for amplifier, frequency multiplier, or oscillator applications in military and industrial equipment. Suitable for use as output driver or pre-driver stages in VHF and UHF equipment.

- Current-Gain—Bandwidth Product —
  f_T = 500 MHz (Min) @ I_C = 50 mAdc
- Power Gain —
  G_{pe} = 10 dB (Min) @ V_{CE} = 12 Vdc
- 1 Watt Minimum Power Output @ f = 175 MHz
- Multiple-Emitter Construction for Excellent High-Frequency Performance

NPN SILICON
RF POWER
TRANSISTOR

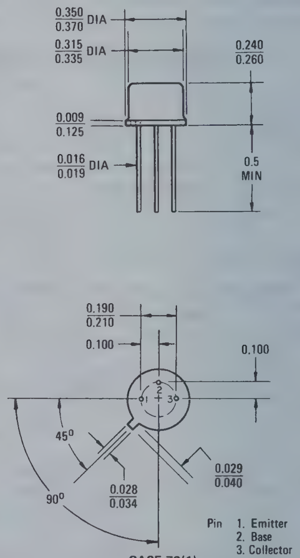


*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	2.0	Vdc
Collector Current — Continuous	I_C	400	mAdc
Base Current — Continuous	I_B	400	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.5 20	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

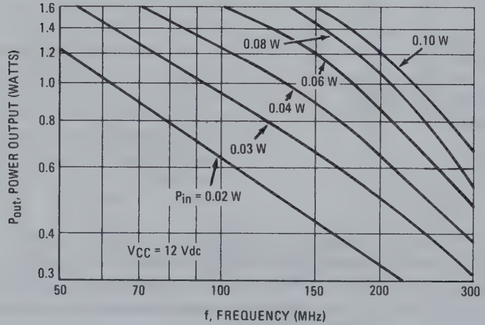
*Indicates JEDEC Registered Data

**Motorola 'guarantees this data in additon to JEDEC registered Data


0.350
0.370 DIA
0.315
0.335 DIA
0.240
0.260
0.009
0.125
0.016
0.019 DIA
0.5
MIN
0.190
0.210
0.100
0.100
2
1
3
45°
90°
0.028
0.034
0.029
0.040
Pin 1. Emitter
2. Base
3. Collector

CASE 79(1)
(TO-39)

FIGURE 1 — POWER OUTPUT versus FREQUENCY

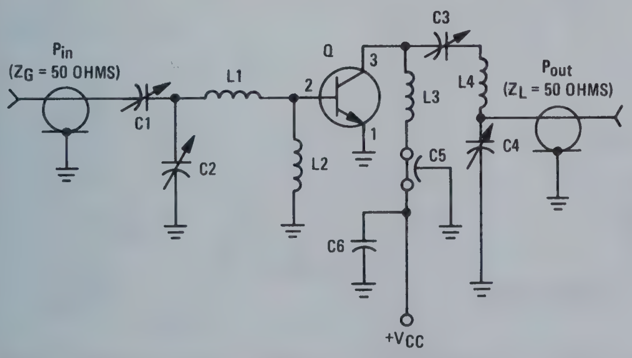


ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
***OFF CHARACTERISTICS**				
Collector-Emitter Sustaining Voltage (I_C = 5.0 mAdc, I_B = 0)	$V_{CEO(sus)}$	20	–	Vdc
Collector-Emitter Sustaining Voltage (I_C = 5.0 mAdc, R_{BE} = 10 ohms)	$V_{CER(sus)}$	40	–	Vdc
Collector Cutoff Current (V_{CE} = 12 Vdc, I_B = 0)	I_{CEO}	–	0.02	mAdc
Collector Cutoff Current (V_{CE} = 40 Vdc, V_{BE} = −1.5 Vdc) (V_{CE} = 12 Vdc, V_{BE} = −1.5 Vdc, T_C = +150°C)	I_{CEV}	– –	0.1 5.0	mAdc
Emitter Cutoff Current (V_{EB} = 2.0 Vdc, I_C = 0)	I_{EBO}	–	0.1	mAdc
***ON CHARACTERISTICS**				
DC Current Gain (I_C = 100 mAdc, V_{CE} = 5.0 Vdc) (I_C = 360 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}	10 5.0	200 –	–
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	–	0.5	Vdc
***DYNAMIC CHARACTERISTICS**				
Current-Gain – Bandwidth Product (I_C = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	f_T	500	–	MHz
Output Capacitance (V_{CB} = 12 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	–	4.0	pF
FUNCTIONAL TEST				
*Power Input (Figure 1) (P_{out} = 1.0 W, Z_S = 50 Ohms, V_{CC} = 12 Vdc, f = 175 MHz)	P_{in}	–	100	mW
Common-Emitter Amplifier Power Gain (P_{in} = 100 mW, Z_S = 50 Ohms, V_{CC} = 12 Vdc, f = 175 MHz)	G_{pe}	10	–	dB
*Collector Efficiency (Figure 1) (P_{out} = 1.0 W, Z_S = 50 Ohms, V_{CC} = 12 Vdc, f = 175 MHz)	η	50	–	%

*Indicates JEDEC Registered Data

FIGURE 1 – 175 MHz RF AMPLIFIER CIRCUIT FOR POWER-OUTPUT TEST



C1, C2,
C3, and C4: 3-30 pF
C5: 1,000 pF
C6: 0.01 μF
L1: 2 turns No. 16 wire, 3/16″ ID, 1/4″ long
L2: Ferrite choke, Z = 450 ohms
L3: 2 turns No. 16 wire, 1/4″ ID, 1/4″ long
L4: 4 turns No. 16 wire, 3/8″ ID, 3/8″ long
Q: 2N4427

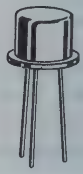
2N4428 (SILICON)

NPN SILICON RF POWER TRANSISTOR

. . . designed primarily for use in large signal VHF and UHF amplifier output stages in military and industrial communications applications.

- High Power Output —
  P_{out} = 0.75 Watt with 10 dB Gain @ f = 500 MHz
- High Current-Gain—Bandwidth Product —
  f_T = 1000 MHz (Typ) @ I_C = 50 mAdc
- Multiple Emitter Construction for Excellent High Frequency Performance

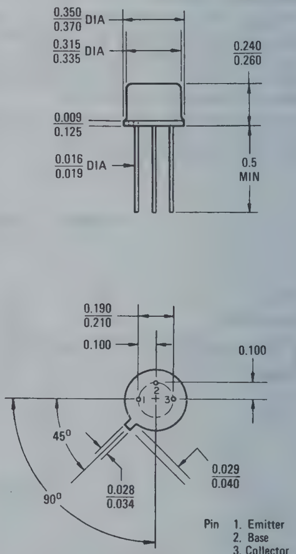
**NPN SILICON
RF POWER
TRANSISTOR**



*MAXIMUM RATINGS

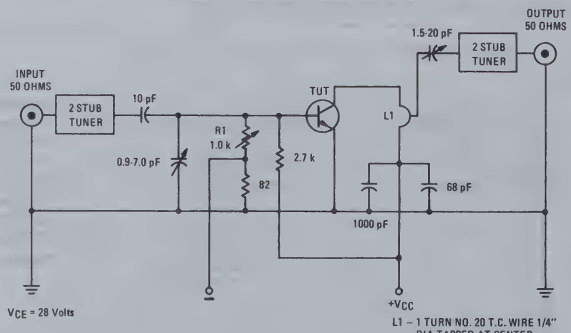
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Collector-Base Voltage	V_{CB}	55	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current — Continuous	I_C	425	mAdc
Base Current — Continuous	I_B	150	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.5 20	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.


0.350
0.370 DIA
0.315
0.335 DIA
0.240
0.260
0.009
0.125
0.016
0.019 DIA
0.5
MIN
0.190
0.210
0.100
0.100
45°
90°
0.028
0.034
0.029
0.040
1
2
3
Pin 1. Emitter
2. Base
3. Collector

CASE 79(1)
(TO-39)

FIGURE 1 — 500 MHz TEST CIRCUIT


INPUT
50 OHMS
2 STUB
TUNER
10 pF
0.9-7.0 pF
R1
1.0 k
82
2.7 k
TUT
L1
1000 pF
68 pF
1.5-20 pF
2 STUB
TUNER
OUTPUT
50 OHMS
+VCC
VCE = 28 Volts

L1 – 1 TURN NO. 20 T.C. WIRE 1/4" DIA TAPPED AT CENTER

Adjust R1 for I_C = 70 mA with no RF Signal Applied

***ELECTRICAL CHARACTERISTICS** (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 20 mAdc, I_B = 0)	$V_{CEO(sus)}$	35	—	—	Vdc
Collector-Emitter Sustaining Voltage (I_C = 20 mAdc, R_{BE} = 10 ohms)	$V_{CER(sus)}$	55	—	—	Vdc
Collector Cutoff Current (V_{CE} = 55 Vdc, V_{BE} = −1.5 Vdc)	I_{CEX}	—	—	1.0	mAdc
Emitter Cutoff Current (V_{EB} = 3.5 Vdc, I_C = 0)	I_{EBO}	—	—	0.1	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 50 mAdc, V_{CE} = 5.0 Vdc) (I_C = 400 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}	 20 5.0	 — —	 200 —	—
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 200 MHz)	f_T	700	1000	—	MHz
Output Capacitance (V_{CB} = 28 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	—	1.2	3.5	pF
FUNCTIONAL TEST					
Power Input (Figure 1) (P_{out} = 750 mW, V_{CE} = 28 Vdc, R_S = 50 Ohms, f = 500 MHz)	P_{in}	—	—	75	mW
Collector Efficiency (Figure 1) (P_{out} = 750 mW, V_{CE} = 28 Vdc, R_S = 50 Ohms, f = 500 MHz)	η	35	—	—	%

*Indicates JEDEC Registered Data.

FIGURE 2 — CURRENT-GAIN—BANDWIDTH PRODUCT

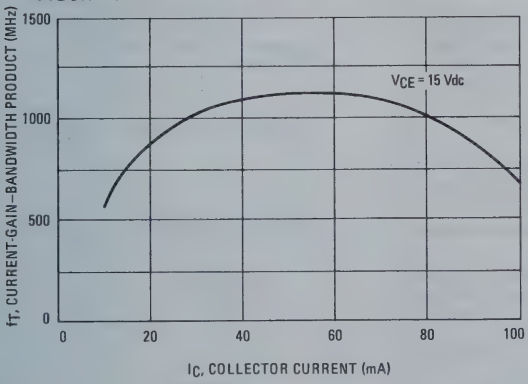
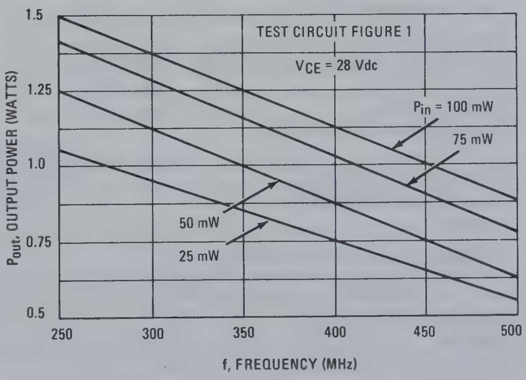
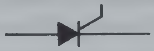


FIGURE 3 — OUTPUT POWER versus FREQUENCY



2N4441 (SILICON)
thru
2N4444



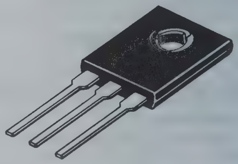
PLASTIC THYRISTORS

. . . designed for high-volume consumer phase-control applications such as motor speed, temperature, and light controls and for switching applications in ignition and starting systems, voltage regulators, vending machines, and lamp drivers requiring:

- Small, Rugged, Thermopad Construction — for Low Thermal Resistance, High Heat Dissipation, and Durability.
- Practical Level Triggering and Holding Characterisitcs — I_{GT} = 7.0 mA, I_H = 6.0 mA (Typ) @ 25°C
- Low "On" Voltage — V_F = 1.0 Volt (Typ) @ 5.0 Amps @ 25°C
- High Surge Current Rating — I_{TSM} = 80 Amps

PLASTIC SILICON CONTROLLED RECTIFIERS

8.0 AMPERES RMS
50 thru 600 VOLTS



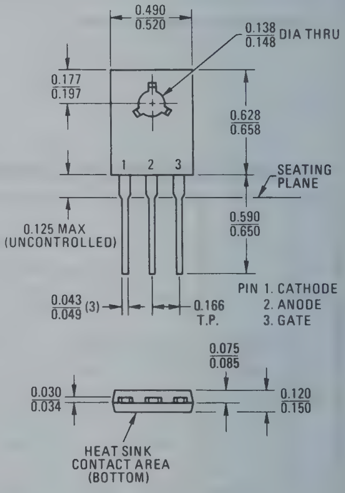
MAXIMUM RATINGS (T_J = 100°C unless otherwise noted)

Rating	Symbol	Value	Unit
*Peak Reverse Blocking Voltage	V_{RRM}		Volts
(Note 1) 2N4441		50	
2N4442		200	
2N4443		400	
2N4444		600	
*Non-Repetative Peak Reverse Blocking Voltage (t = 5.0 ms (max) duration)	V_{RSM}		Volts
2N4441		75	
2N4442		300	
2N4443		500	
2N4444		700	
*Forward Current RMS (All Conduction Angles)	$I_{T(RMS)}$	8.0	Amps
*Peak Forward Surge Current (1/2 cycle, 60 Hz)	I_{TSM}	80	Amps
Circuit Fusing Considerations (T_J = −40 to +100°C; t = 1.0 to 8.3 ms)	I^2t	25	A^2s
*Peak Gate Power	P_{GM}	5.0	Watts
*Average Gate Power	$P_{G(AV)}$	0.5	Watt
*Peak Gate Current	I_{GM}	2.0	Amps
*Peak Gate Voltage	V_{GM}	10	Volts
*Operating Junction Temperature Range	T_J	−40 to +100	°C
*Storage Temperature Range	T_{stg}	−40 to +150	°C
Mounting Torque (6-32 screw) (Note 2)	—	8.0	in. lb

THERMAL CHARACTERISITCS

Characteristic	Symbol	Typ	Max	Unit
*Thermal Resistance, Junction to Case	$R\theta_{JC}$	—	2.5	°C/W
Thermal Resistance Junction to Ambient	$R\theta_{JA}$	40	—	°C/W

*Indicates JEDEC Registered Data.


0.490
0.520
0.138
0.148 DIA THRU
0.177
0.197
0.628
0.658
1 2 3
SEATING PLANE
0.125 MAX (UNCONTROLLED)
0.590
0.650
PIN 1. CATHODE
2. ANODE
3. GATE
0.043
0.049 (3)
0.166 T.P.
0.075
0.085
0.030
0.034
0.120
0.150
HEAT SINK CONTACT AREA (BOTTOM)

CASE 90-04

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
*Peak Forward Blocking Voltage (T_J = 100°C) Note 1 2N4441 2N4442 2N4443 2N4444	V_{DRM}	 50 200 400 600	 – – –	 – – –	Volts
Peak Forward Blocking Current (Rated V_{DRM} @ T_J = 100°C, gate open)	I_{DRM}	 –	 –	 2.0	mA
Peak Reverse Blocking Current (Rated V_{DRM} @ T_J = 100°C, gate open)	I_{RRM}	 –	 –	 2.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage – 7.0 Vdc, R_L = 100 ohms) T_C = 25°C *T_C = –40°C	I_{GT}	 – –	 7.0 –	 30 60	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms) T_C = 25°C *(Anode Voltage = 7.0 Vdc, R_L = 100 ohms) T_C = –40°C *(Anode Voltage = Rated V_{FOM}, R_L = 100 ohms) T_J = 100°C	V_{GT}	 – – 0.2	 0.75 – –	 1.5 2.5 –	Volts
Forward "On" Voltage (I_F = 5.0 A peak) *(I_F = 15.7 A peak)	V_T	 – –	 1.0 –	 1.5 2.0	Volts
Holding Current (Anode Voltage = 7.0 Vdc, gate open) T_C = 25°C *T_C = –40°C	I_H	 – –	 6.0 –	 40 70	mA
Turn-On Time (I_F = 5.0 A, I_{GT} = 20 mA)	t_{on}	 –	 1.0	 –	μs
Turn-Off Time (I_F = 5.0 A, I_R = 5.0 A) (I_F = 5.0 A, I_R = 5.0 A, T_J = 100°C)	t_{off}	 – –	 15 20	 – –	μs
Forward Voltage Application Rate (T_J = 100°C)	dv/dt	 –	 50	 –	V/μs

*Indicates JEDEC Registered Data

Note 1. Ratings apply for zero or negative gate voltage but positive gate voltage shall not be applied concurrently with a negative potential on the anode. When checking forward or reverse blocking capability, thyristor devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage.

Note 2. Torque rating applies with use of torque washer (Shakeproof WD19522 #6 or equivalent). Mounting torque in excess of 8 in. lbs. does not appreciably lower case-to-sink thermal resistance. Anode lead and heatsink contact pad are common.

For soldering purposes (either terminal connection or device mounting), soldering temperatures shall not exceed +225°C.

FIGURE 1 – MAXIMUM FORWARD VOLTAGE

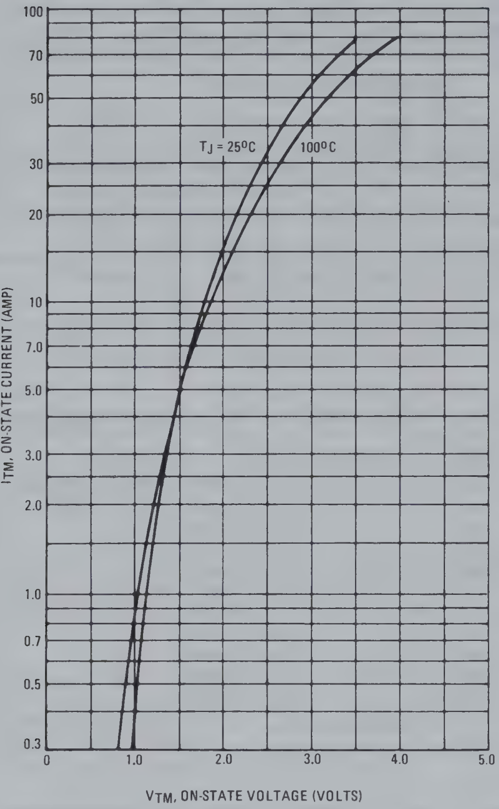


FIGURE 2 – POWER DISSIPATION

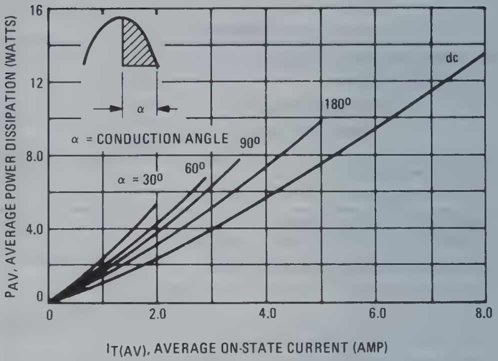


FIGURE 3 – AVERAGE CURRENT DERATING

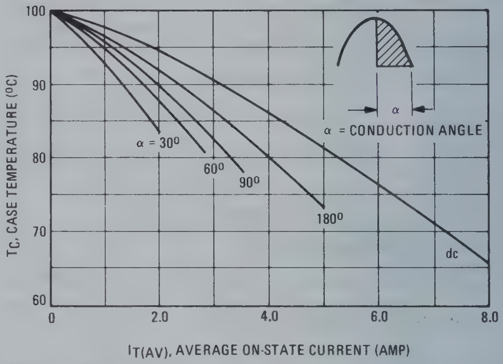


FIGURE 4 – THERMAL RESPONSE

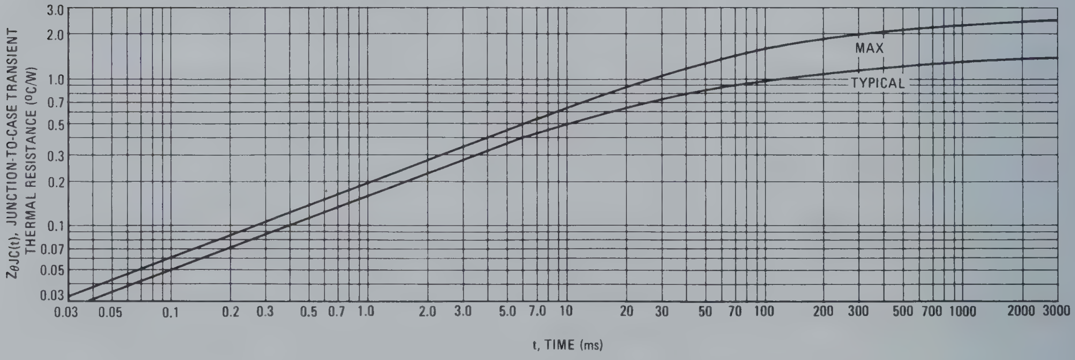


FIGURE 5 – MAXIMUM ALLOWABLE SURGE CURRENT

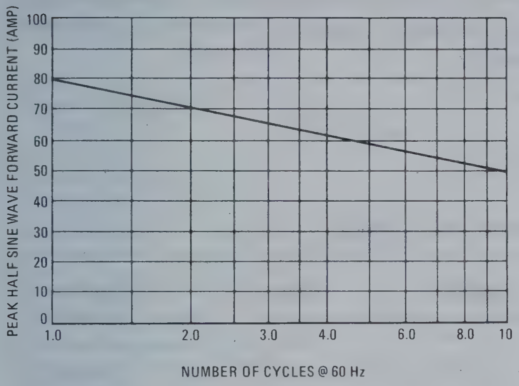


FIGURE 6 – TYPICAL HOLDING CURRENT

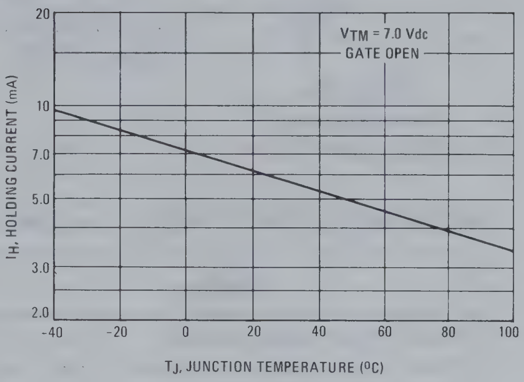


FIGURE 7 – TYPICAL GATE TRIGGER CURRENT

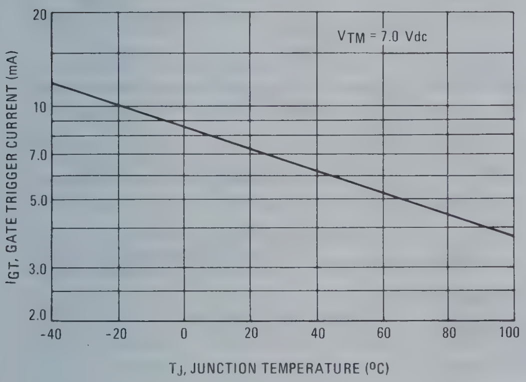
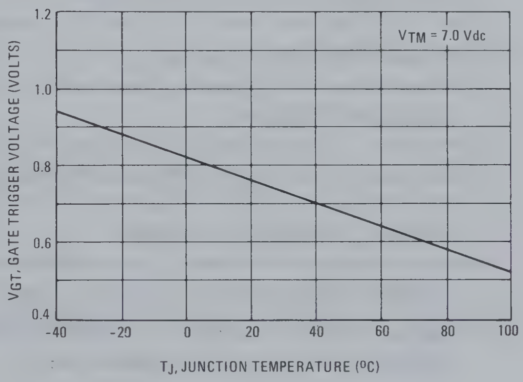


FIGURE 8 – TYPICAL GATE TRIGGER VOLTAGE



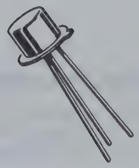
SELECTED THYRISTOR-TRIGGER APPLICATION NOTES

AN-240	–SCR Power Control Fundamentals
AN-290A	–Mounting Procedure for, and Thermal Aspects of, Thermopad Plastic Power Devices
AN-295	–Suppressing RFI in Thyristor Circuits
AN-422	–Testers for Thyristors and Trigger Diodes
AN-453	–Zero Point Switching Techniques

To obtain copies of these notes list the AN number(s) on your company letterhead and send your request to:

Technical Information Center
Motorola Semiconductor Products, Inc.
P.O. Box 20924
Phoenix, Arizona 85036

2N4851 thru 2N4853 (SILICON)



CASE 22A
(TO-18 Modified)
Lead 3 connected to case

Silicon annular unijunction transistors designed for pulse and timing circuits, sensing circuits, and thyristor trigger circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	$P_D{}^*$	300	mW
RMS Emitter Current	I_e	50	mA
Peak-Pulse Emitter Current **	$i_e{}^{**}$	1.5	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage †	$V_{B2B1}{}^{\dagger}$	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 3.0 mW/°C increase in ambient temperature.
** Duty cycle ≦ 1%, PRR = 10 PPS (see figure 6)
† Based upon power dissipation at T_A = 25°C

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

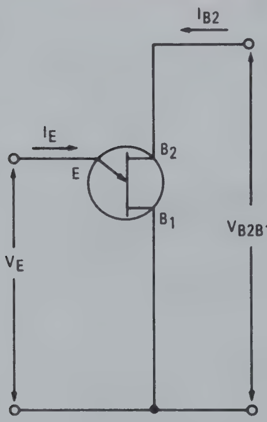


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

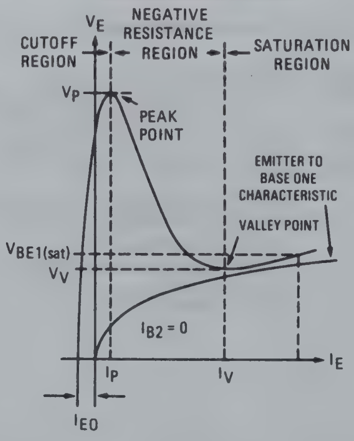
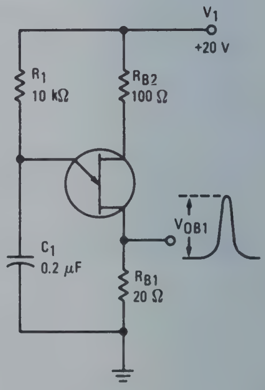


FIGURE 3 — V_{OB1} TEST CIRCUIT



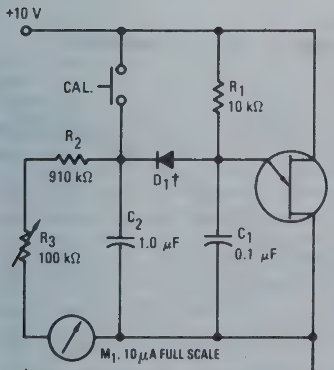
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Figure No.	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio* (V_{B2B1} = 10 V) 2N4851 2N4852, 2N4853	4, 8	η*	0.56 0.70	— —	0.75 0.85	—
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	11, 12	R_{BB}	4.7	—	9.1	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65 to +125°C)	12	αR_{BB}	0.2	—	0.8	%/°C
Emitter Saturation Voltage** (V_{B2B1} = 10 V, I_E = 50 mA)		$V_{EB1(sat)}$**	—	2.5	—	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	—	15	—	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0) 2N4851, 2N4852 2N4853	7	I_{EB2O}	— —	— —	0.1 0.05	μA
Peak-Point Emitter Current (V_{B2B1} = 25 V) 2N4851, 2N4852 2N4853	9, 10	I_P	— —	— —	2.0 0.4	μA
Valley-Point Current** (V_{B2B1} = 20 V, R_{B2} = 100 ohms) 2N4851 2N4852 2N4853	13, 14	I_V**	2.0 4.0 6.0	— — —	— — —	mA
Base-One Peak Pulse Voltage 2N4851 2N4852 2N4853	3, 17	V_{OB1}	3.0 5.0 6.0	— — —	— — —	Volts
Maximum Frequency of Oscillation	5	$f_{(max)}$	1.0	1.25	—	MHz

* η, Intrinsic standoff ratio, is defined in terms of the peak-point voltage. V_P. by means of the equation: $V_P = \eta V_{B2B1} + V_F$, where V_F is about 0.49 volt at 25°C @ I_F = 10 μA and decreases with temperature at about 2.5 mV/°C. The test circuit is shown in Figure 4. Components R_1, C_1, and the UJT form a relaxation oscillator; the remaining circuitry serves as a peak-voltage detector. The forward drop of Diode D_1 compensates for V_F. To use, the "cal" button is pushed, and R_3 is adjusted to make the current meter, M_1, read full scale. When the "cal" button is released, the value of η is read directly from the meter, if full scale on the meter reads 1.0.

** Use pulse techniques: PW ≈ 300 μs, duty cycle ≦ 2.0% to avoid internal heating, which may result in erroneous readings.

FIGURE 4 — η TEST CIRCUIT


+10 V
CAL.
R1
10 kΩ
R2
910 kΩ
D1†
C2
1.0 µF
C1
0.1 µF
R3
100 kΩ
M1, 10 µA FULL SCALE

†D1, diode with the following characteristics:
V_F = 0.49 V @ I_F = 10 μA
I_R ≦ 2.0 μA @ V_R = 20 V

FIGURE 5 — $f_{(max)}$ TEST CIRCUIT

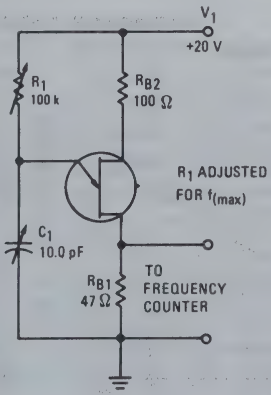
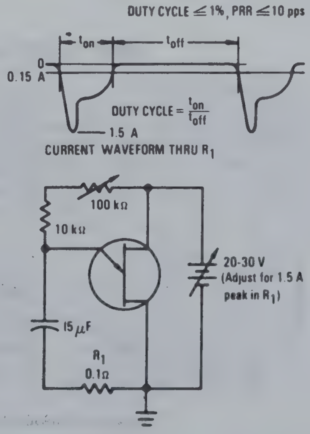

V1
+20 V
R1
100 k
RB2
100 Ω
R1 ADJUSTED FOR f(max)
C1
10.0 pF
RB1
47 Ω
TO FREQUENCY COUNTER

FIGURE 6 — PRR TEST CIRCUIT AND WAVEFORM


DUTY CYCLE ≤ 1%, PRR ≤ 10 pps
ton
toff
0
0.15 A
DUTY CYCLE = ton/toff
1.5 A
CURRENT WAVEFORM THRU R1
100 kΩ
10 kΩ
20-30 V (Adjust for 1.5 A peak in R1)
15 µF
R1
0.1Ω

TYPICAL CHARACTERISTICS

FIGURE 7 — EMITTER REVERSE CURRENT

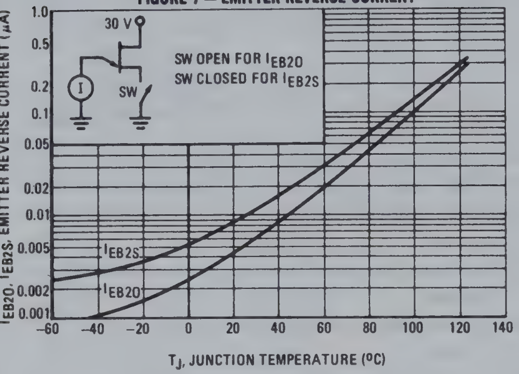
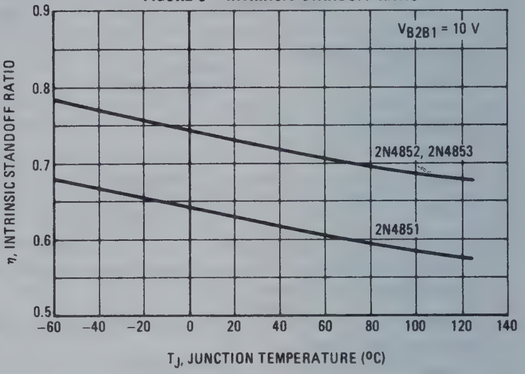


FIGURE 8 — INTRINSIC STANDOFF RATIO



PEAK POINT CURRENT

FIGURE 9 — EFFECT OF VOLTAGE

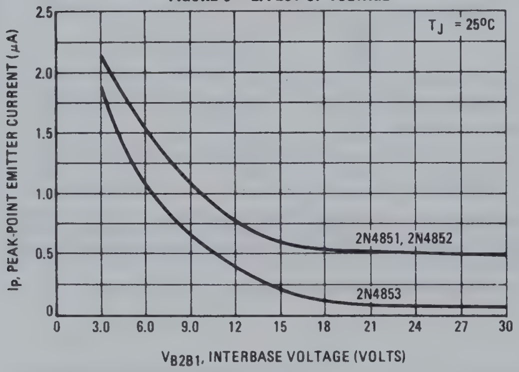
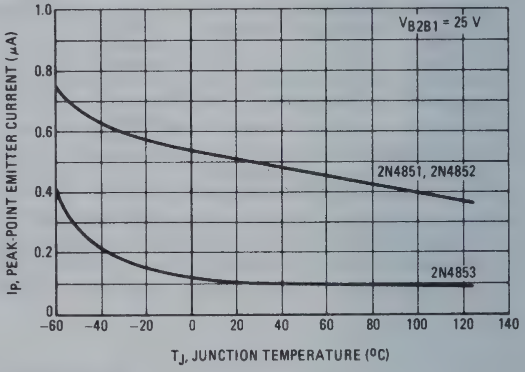


FIGURE 10 — EFFECT OF TEMPERATURE



INTERBASE RESISTANCE

FIGURE 11 — EFFECT OF VOLTAGE

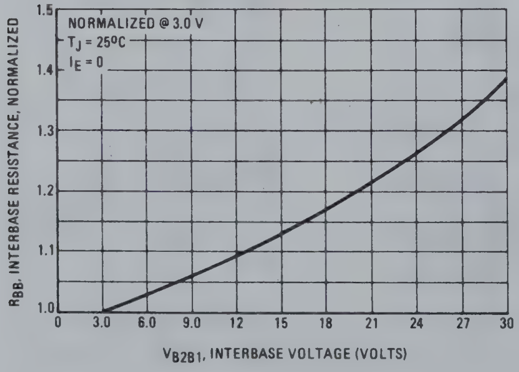
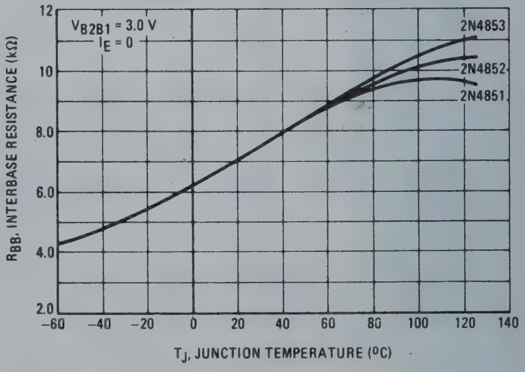


FIGURE 12 — EFFECT OF TEMPERATURE



TYPICAL CHARACTERISTICS

VALLEY CURRENT

FIGURE 13 — EFFECT OF VOLTAGE

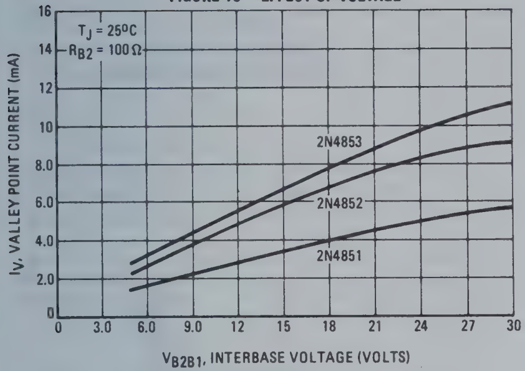
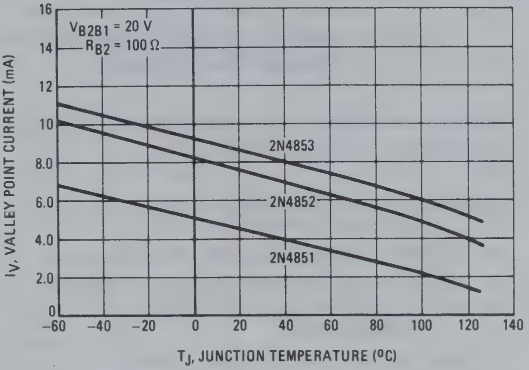


FIGURE 14 — EFFECT OF TEMPERATURE



VALLEY VOLTAGE

FIGURE 15 — EFFECT OF VOLTAGE

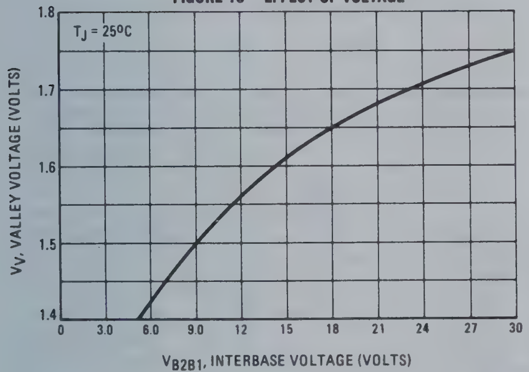


FIGURE 16 — EFFECT OF TEMPERATURE

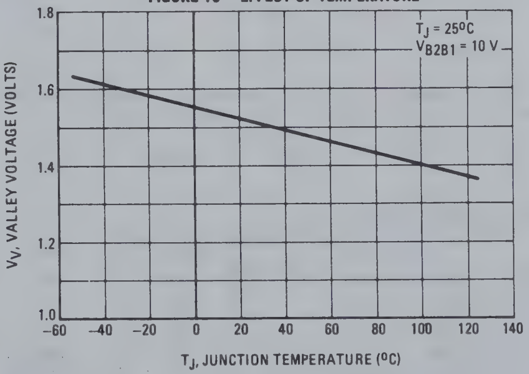
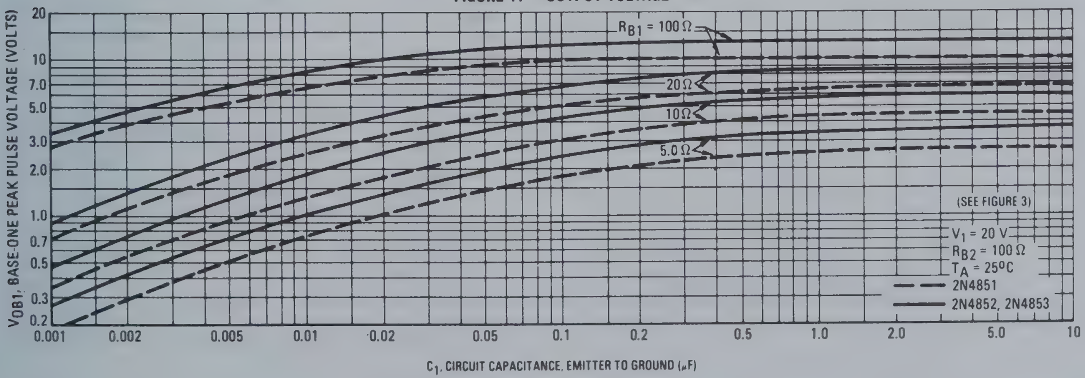


FIGURE 17 — OUTPUT VOLTAGE



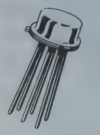
2N4854 (SILICON)
2N4855

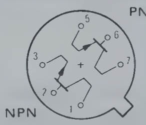
SILICON ANNULAR COMPLEMENTARY-PAIR DUAL TRANSISTORS

. . . designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry.

- Collector-Emitter Breakdown Voltage — BV_{CEO} = 40 Vdc (Min)
- All Leads Isolated Electrically for Design Flexibility
- DC Current Gain Specified — 0.1 mAdc to 300 mAdc
- High Current-Gain—Bandwidth Product — f_T = 200 MHz (Min)
- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)}$ = 0.4 Vdc (Max) @ I_C = 150 mAdc
- NPN Transistor Similar to the 2N2218 or 2N2219
- PNP Transistor Similar to the 2N2904 or 2N2905

NPN-PNP COMPLEMENTARY SILICON TRANSISTORS



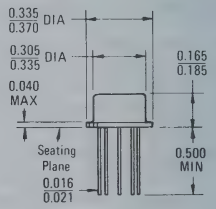

PNP
NPN
1
2
3
5
6
7
+

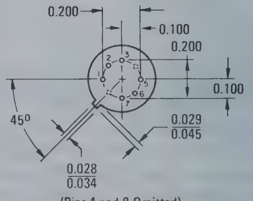
PINS 4 AND 8 OMITTED

Pin Connections, Bottom View

MAXIMUM RATINGS (Each Side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	600		mAdc
Storage Temperature Range	T_{stg}	-65 to +200		°C
Operating Junction Temperature	T_J	+175		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 2.0	600 4.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.0 6.67	2.0 13.33	Watts mW/°C


0.335
0.370 DIA
0.305
0.335 DIA
0.165
0.185
0.040
MAX
Seating
Plane
0.500
MIN
0.016
0.021


0.200
0.100
0.200
0.100
45°
0.029
0.045
0.028
0.034
1
2
3
5
6
7

(Pins 4 and 8 Omitted)
All Leads Electrically Isolated from Case

CASE 654-02

ELECTRICAL CHARACTERISTICS (Each Side) ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (1) (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	40	–	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, I_B = 0)		I_{CEO}	–	10	nAdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0, $T_A = 150^{\circ}C$)		I_{CBO}	–	10	μAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)		I_{EBO}	–	10	nAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			–
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N4854		35	–	
	2N4855		20	–	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N4854		50	–	
	2N4855		25	–	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N4854		75	–	
	2N4855		35	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) (1)	2N4854		100	300	
	2N4855		40	120	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc) (1)	2N4854		50	–	
	2N4855		20	–	
(I_C = 300 mAdc, V_{CE} = 10 Vdc) (1)	2N4854		35	–	
	2N4855		20	–	
Collector-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	–	0.4	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$	0.75	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	200	–	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{cb}	–	8.0	pF
Input Impedance		h_{ie}			k ohms
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N4854		1.5	9.0	
	2N4855		0.75	4.5	
Small-Signal Current Gain		h_{fe}			–
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N4854		60	300	
	2N4855		30	150	
Output Admittance		h_{oe}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N4854		–	50	
	2N4855		–	25	
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz)		NF	–	8.0	dB
SWITCHING CHARACTERISTICS					
Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc)	t_d	–	20	ns
Rise Time		t_r	–	40	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 150 mAdc, $I_{B1} = I_{B2}$ = 15 mAdc)	t_s	–	280	ns
Fall Time		t_f	–	70	ns

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N4856, A (SILICON)
thru
2N4861, A

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

Depletion Mode (Type A) symmetrical Field-Effect transistors designed for low-power switching and chopper applications.

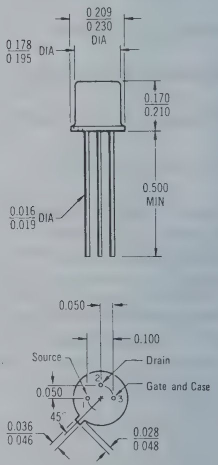
- Low Drain-Source "ON" Resistance —
  $r_{ds(on)}$ = 25 Ohms (Max) @ f = 1.0 kHz – 2N4856,A, 2N4859,A
- Low Drain Cutoff Current —
  $I_{D(off)}$ = 250 pAdc (Max) @ V_{DS} = 15 Vdc

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS
(Type A)

*MAXIMUM RATINGS

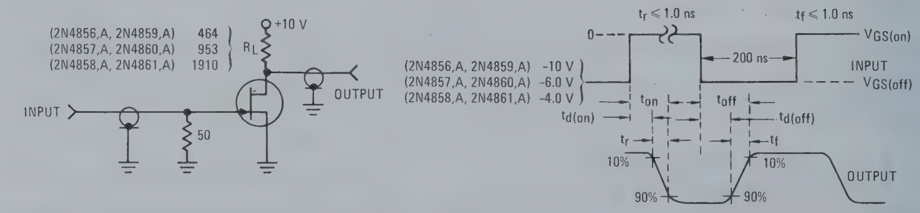
Rating	Symbol	2N4856,A 2N4857,A 2N4858,A	2N4859,A 2N4860,A 2N4861,A	Unit
Drain-Gate Voltage	V_{DG}	+40	+30	Vdc
Drain-Source Voltage	V_{DS}	+40	+30	Vdc
Reverse Gate-Source Voltage	V_{GSR}	-40	-30	Vdc
Forward Gate Current	I_{GF}	50		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.4		mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

*Indicates JEDEC Registered Data.


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
Source
Drain
Gate and Case
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

CASE 22 (4)
(TO-18)

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT


(2N4856,A, 2N4859,A) 464
(2N4857,A, 2N4860,A) 953
(2N4858,A, 2N4861,A) 1910
RL
+10 V
OUTPUT
INPUT
50
tr ≤ 1.0 ns
tf ≤ 1.0 ns
0
VGS(on)
200 ns
INPUT
VGS(off)
(2N4856,A, 2N4859,A) -10 V
(2N4857,A, 2N4860,A) -6.0 V
(2N4858,A, 2N4861,A) -4.0 V
ton
toff
td(on)
td(off)
tr
tf
10%
10%
90%
90%
OUTPUT

TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: a. The input waveforms are supplied by a generator with the following characteristics:
Z_{out} = 50 ohms, Duty Cycle ≈ 2.0%.
b. Waveforms are monitored on an oscilloscope with the following characteristics:
$t_r \leqslant 0.75$ ns, $R_{in} \geqslant 1.0$ megohm, $C_{in} \leqslant 2.5$ pF.

***ELECTRICAL CHARACTERISTICS** (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)	2N4856,A,2N4857,A,2N4858,A	$V_{(BR)GSS}$	-40	–	Vdc
	2N4859,A,2N4860,A,2N4861,A		-30	–	
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 0.5 nAdc)	2N4856,A,2N4859,A	$V_{GS(off)}$	-4.0	-10	Vdc
	2N4857,A,2N4860,A		-2.0	-6.0	
	2N4858,A,2N4861,A		-0.8	-4.0	
Gate Reverse Current (V_{GS} = -20 Vdc, V_{DS} = 0)	2N4856,A,2N4857,A,2N4858,A	I_{GSS}	–	0.25	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0)	2N4859,A,2N4860,A,2N4861,A		–	0.25	
(V_{GS} = -20 Vdc, V_{DS} = 0, T_A = 150°C)	2N4856,A,2N4857,A,2N4858,A		–	0.5	μAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 150°C)	2N4859,A,2N4860,A,2N4861,A		–	0.5	
Drain Cutoff Current (V_{DS} = 15 Vdc, V_{GS} = -10 Vdc)		$I_{D(off)}$	–	0.25	nAdc
(V_{DS} = 15 Vdc, V_{GS} = -10 Vdc, T_A = 150°C)			–	0.5	μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (Note 1) (V_{DS} = 15 Vdc, V_{GS} = 0)	2N4856,A,2N4859,A	I_{DSS}	50	–	mAdc
	2N4857,A,2N4860,A		20	100	
	2N4858,A,2N4861,A		8.0	80	
Drain-Source "ON" Voltage (I_D = 20 mAdc, V_{GS} = 0)	2N4856,A,2N4859,A	$V_{DS(on)}$	–	0.75	Vdc
(I_D = 10 mAdc, V_{GS} = 0)	2N4857,A,2N4860,A		–	0.5	
(I_D = 5.0 mAdc, V_{GS} = 0)	2N4858,A,2N4861,A		–	0.5	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N4856,A,2N4859,A	$r_{ds(on)}$	–	25	Ohms
	2N4857,A,2N4860,A		–	40	
	2N4858,A,2N4861,A		–	60	
Input Capacitance (V_{DS} = 0, V_{GS} = -10 Vdc, f = 1.0 MHz)	2N4856 thru 2N4861	C_{iss}	–	18	pF
	2N4856 A thru 2N4861 A			10	
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = -10 Vdc, f = 1.0 MHz)	2N4856 thru 2N4861	C_{rss}	–	8.0	pF
	2N4856 A,2N4859 A		–	4.0	
	2N4857 A,2N4858 A,2N4860 A,2N4861 A		–	3.5	

SWITCHING CHARACTERISTICS (See Figure 1) (Note 2)

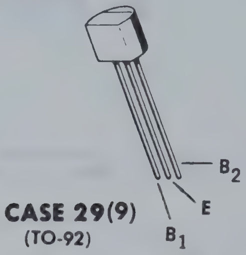
Turn-On Delay Time	Conditions for 2N4856,A, 2N4859,A: (V_{DD} = 10 Vdc, $I_{D(on)}$ = 20 mAdc, $V_{GS(on)}$ = 0, $V_{GS(off)}$ = -10 Vdc)	2N4856, 2N4859	$t_{d(on)}$	–	6.0	ns
		2N4856A, 2N4859A		–	5.0	
		2N4857, 2N4860		–	6.0	
		2N4857A, 2N4860A		–	6.0	
		2N4858, 2N4861		–	10	
		2N4858A, 2N4861A		–	8.0	
Rise Time	Conditions for 2N4857,A, 2N4860,A: (V_{DD} = 10 Vdc, $I_{D(on)}$ = 10 mAdc, $V_{GS(on)}$ = 0, $V_{GS(off)}$ = -6.0 Vdc)	2N4856,A, 2N4859,A	t_r	–	3.0	ns
		2N4857,A, 2N4860,A		–	4.0	
		2N4858, 2N4861		–	10	
		2N4858A, 2N4861A		–	8.0	
Turn-Off Time		2N4856, 2N4859	t_{off}	–	25	
	Conditions for 2N4858,A, 2N4861,A: (V_{DD} = 10 Vdc, $I_{D(on)}$ = 5.0 mAdc, $V_{GS(on)}$ = 0, $V_{GS(off)}$ = -4.0 Vdc)	2N4856A, 2N4859A		–	20	ns
		2N4857, 2N4860		–	50	
		2N4857A, 2N4860A		–	40	
		2N4858, 2N4861		–	100	
		2N4858A, 2N4861A		–	80	

*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width = 100 ms, Duty Cycle ≤ 10%.

Note 2: The $I_{D(on)}$ values are nominal; exact values vary slightly with transistor parameters.

2N4870 (SILICON)
2N4871



CASE 29(9)
(TO-92)

PN unijunction transistors designed for use in pulse and timing circuits, sensing circuits and thyristor trigger circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D*	300	mW
RMS Emitter Current	I_e	50	mA
Peak-Pulse Emitter Current**	i_e**	1.5	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage†	V_{B2B1}†	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*Derate 3.0 mW/°C increase in ambient temperature.
**Duty cycle ≦ 1%, PRR = 10 PPS (see Figure 5).
†Based upon power dissipation at T_A = 25°C.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

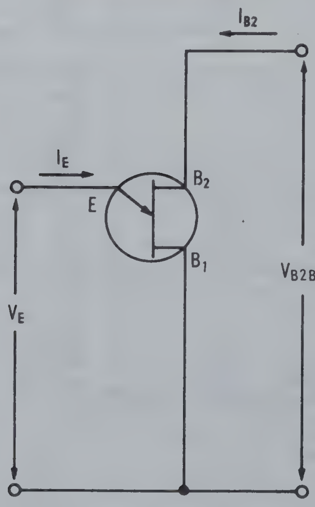
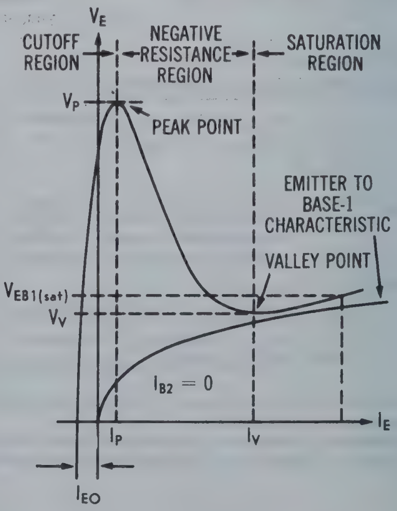


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio* (V_{B2B1} = 10 V)	2N4870 2N4871	4, 7	η*	0.56 0.70	- -	0.75 0.85	-
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)		10, 11	R_{BB}	4.0	6.0	9.1	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65 to +125°C)		11	αR_{BB}	0.10	-	0.90	%/°C
Emitter Saturation Voltage** (V_{B2B1} = 10 V, I_E = 50 mA)			$V_{EB1(sat)}$**	-	2.5	-	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)			$I_{B2(mod)}$	-	15	-	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)		6	I_{EB2O}	-	0.005	1.0	µA
Peak-Point Emitter Current (V_{B2B1} = 25 V)		8, 9	I_P	-	1.0	5.0	µA
Valley-Point Current** (V_{B2B1} = 20 V, R_{B2} = 100 ohms)	2N4870 2N4871	12, 13	I_V**	2.0 4.0	5.0 7.0	- -	mA
Base-One Peak Pulse Voltage	2N4870 2N4871	3, 16	V_{OB1}	3.0 5.0	6.0 8.0	- -	Volts

* η Intrinsic standoff ratio, is defined in terms of peak-point voltage, V_P, by means of the equation: $V_P = \eta V_{B2B1} + V_F$, where V_F is approximately 0.49 volt at 25°C @ I_F = 10 µA and decreases with temperature at approximately 2.5 mV/°C. The test circuit is shown in Figure 4. Components R_1, C_1, and the UJT form a relaxation oscillator, the remaining circuitry serves as a peak-voltage detector. The forward drop of Diode D_1 compensates for V_F. To use, the "cal" button is pushed, and R_3 is adjusted to make the current meter, M_1, read full scale. When the "cal" button is released, the value of η is read directly from the meter, if full scale on the meter reads 1.0.

** Use pulse techniques: PW ≈ 300 µs, duty cycle ≦ 2.0% to avoid internal heating, which may result in erroneous readings.

FIGURE 3 — V_{OB1} TEST CIRCUIT

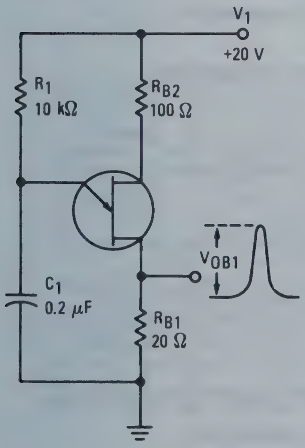
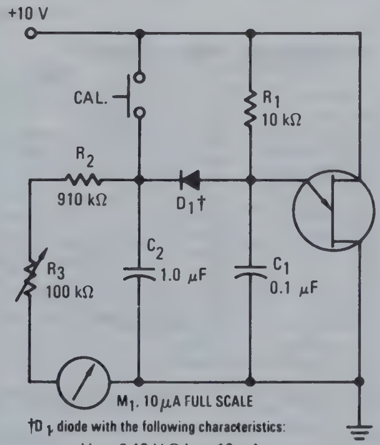
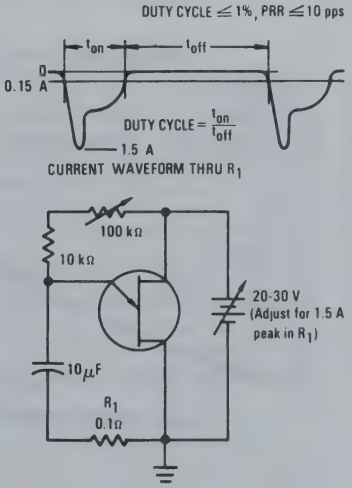

V1
+20 V
R1
10 kΩ
RB2
100 Ω
VOB1
C1
0.2 µF
RB1
20 Ω

FIGURE 4 — η TEST CIRCUIT


+10 V
CAL.
R1
10 kΩ
R2
910 kΩ
D1†
R3
100 kΩ
C2
1.0 µF
C1
0.1 µF
M1, 10 µA FULL SCALE

†D_1, diode with the following characteristics:
V_F = 0.49 V @ I_F = 10 µA
I_R ≦ 2.0 µA @ V_R = 20 V

FIGURE 5 — PRR TEST CIRCUIT AND WAVEFORM


DUTY CYCLE ≦ 1%, PRR ≦ 10 pps
ton
toff
0
0.15 A
DUTY CYCLE = ton/toff
1.5 A
CURRENT WAVEFORM THRU R1
100 kΩ
10 kΩ
20-30 V (Adjust for 1.5 A peak in R1)
10 µF
R1
0.1Ω

TYPICAL CHARACTERISTICS

FIGURE 6 — EMITTER REVERSE CURRENT

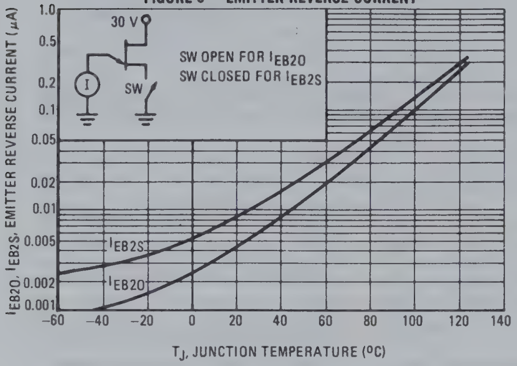
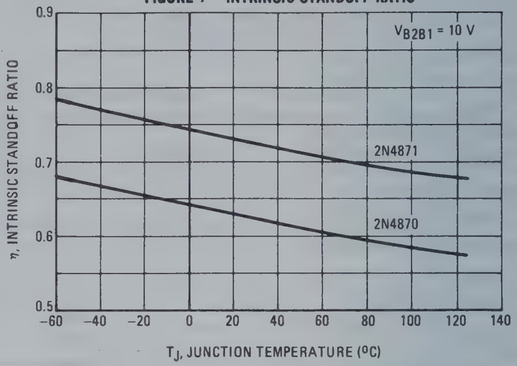


FIGURE 7 — INTRINSIC STANDOFF RATIO



PEAK POINT CURRENT

FIGURE 8 — EFFECT OF VOLTAGE

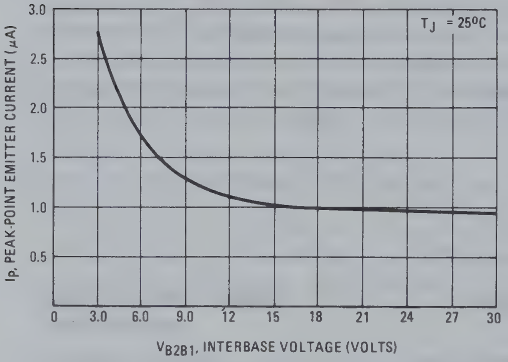
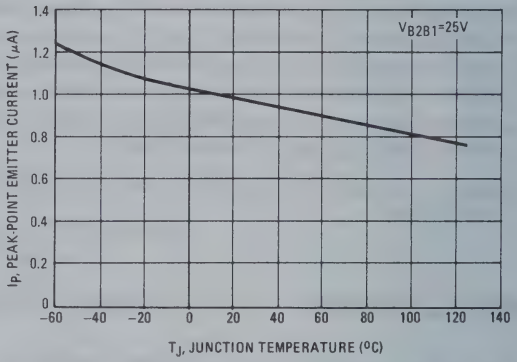


FIGURE 9 — EFFECT OF TEMPERATURE



INTERBASE RESISTANCE

FIGURE 10 — EFFECT OF VOLTAGE

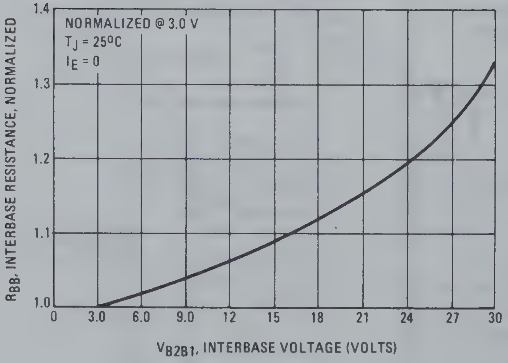
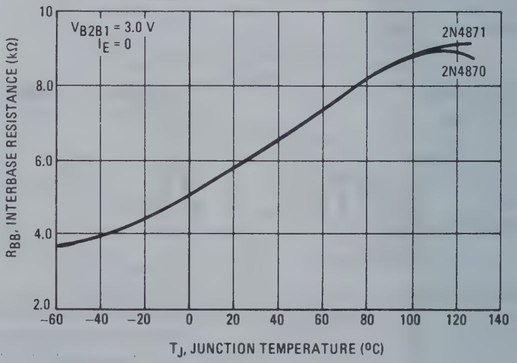


FIGURE 11 — EFFECT OF TEMPERATURE



TYPICAL CHARACTERISTICS

VALLEY CURRENT

FIGURE 12 — EFFECT OF VOLTAGE

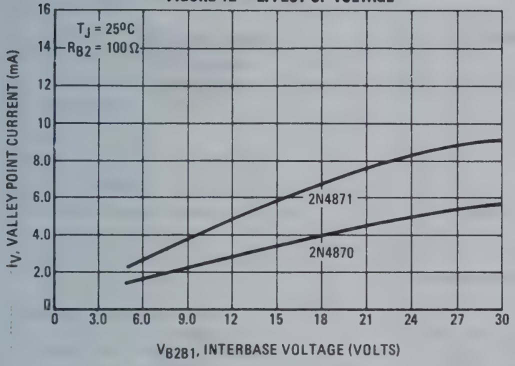
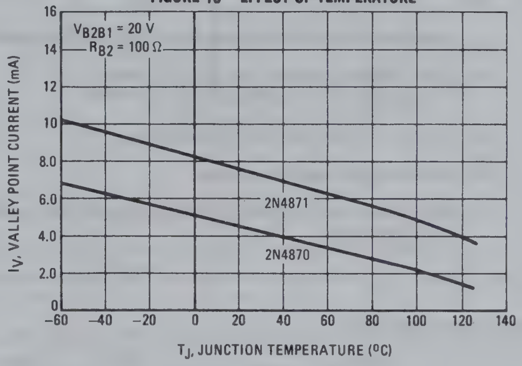


FIGURE 13 — EFFECT OF TEMPERATURE



VALLEY VOLTAGE

FIGURE 14 — EFFECT OF VOLTAGE

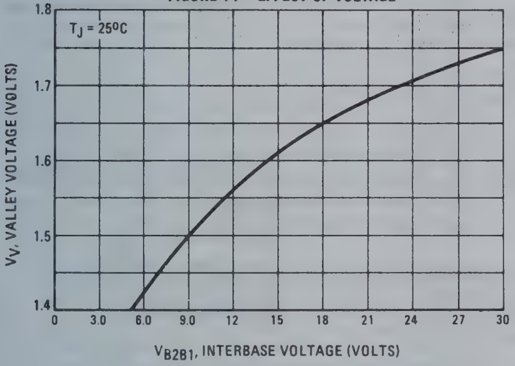


FIGURE 15 — EFFECT OF TEMPERATURE

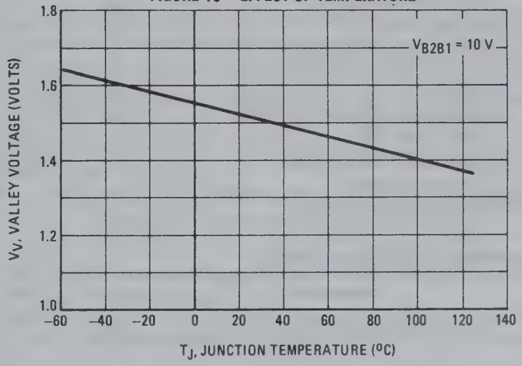
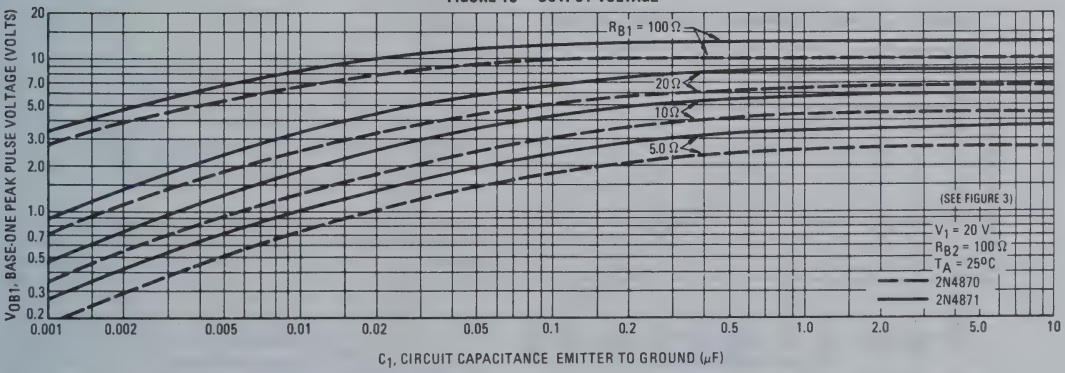


FIGURE 16 — OUTPUT VOLTAGE



2N4877 (SILICON)

MEDIUM-POWER NPN SILICON TRANSISTOR

. . . designed for switching and wide band amplifier applications.

- Low Collector-Emitter Saturation Voltage – $V_{CE(sat)} = 1.0$ Vdc (Max) @ $I_C = 4.0$ Amp
- DC Current Gain Specified to 4 Amperes
- Excellent Safe Operating Area
- Packaged in the Compact TO-39 Case for Critical Space-Limited Applications.

* MAXIMUM RATINGS

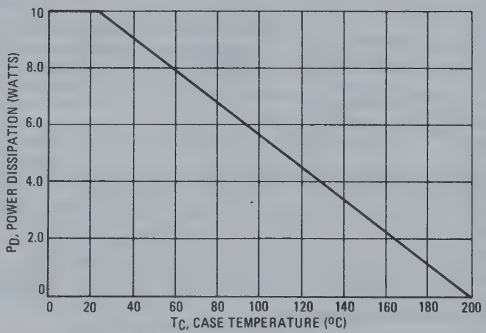
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	70	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current – Continuous	I_C	4.0	Adc
Base Current	I_B	1.0	Adc
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	10 57.2	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	17.5	°C/W

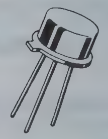
FIGURE 1 – POWER-TEMPERATURE DERATING CURVE

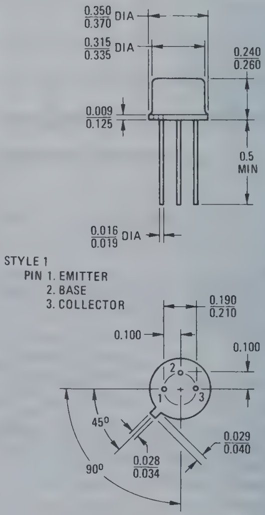


Safe Area Curves are indicated by Figure 2. All limits are applicable and must be observed.

4 AMPERE
POWER TRANSISTOR

NPN SILICON
60 VOLTS
10 WATTS




0.350/0.370 DIA
0.315/0.335 DIA
0.240/0.260
0.009/0.125
0.5 MIN
0.016/0.019 DIA
STYLE 1
PIN 1. EMITTER
2. BASE
3. COLLECTOR
0.190/0.210
0.100
0.100
1
2
3
45°
90°
0.028/0.034
0.029/0.040

To convert inches to millimeters multiply by 25.4

All JEDEC dimensions and notes apply

CASE 79 (1)

TO-39

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1) (I_C = 200 mAdc, I_B = 0)	$V_{CEO(sus)}$	60	–	Vdc
Collector Cutoff Current (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 100°C)	I_{CEX}	– –	100 1.0	µAdc mAdc
Collector Cutoff Current (V_{CB} = 70 Vdc, I_E = 0)	I_{CBO}	–	100	µAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	–	100	µAdc
ON CHARACTERISTICS(1)				
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc) (I_C = 4.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	30 20	– 100	–
Collector-Emitter Saturation Voltage (I_C = 4.0 Adc, I_B = 0.4 Adc)	$V_{CE(sat)}$	–	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 4.0 Adc, I_B = 0.4 Adc)	$V_{BE(sat)}$	–	1.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 0.25 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz) (I_C = 0.25 Adc, V_{CE} = 10 Vdc, f = 10 MHz)**	f_T	4.0 30	– –	MHz
SWITCHING CHARACTERISTICS				
Rise Time (V_{CC} = 25 Vdc, I_C = 4.0 Adc, I_{B1} = 0.4 Adc)	t_r	–	100	ns
Storage Time (V_{CC} = 25 Vdc, I_C = 4.0 Adc, I_{B1} = I_{B2} = 0.4 Adc)	t_s	–	1.5	µs
Fall Time (V_{CC} = 25 Vdc, I_C = 4.0 Adc, I_{B1} = I_{B2} = 0.4 Adc)	t_f	–	500	ns

*Indicates JEDEC Registered Data.
**Motorola guarantees this value in addition to JEDEC Registered Data.
Note 1: Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

FIGURE 2 – ACTIVE-REGION SAFE OPERATING AREA

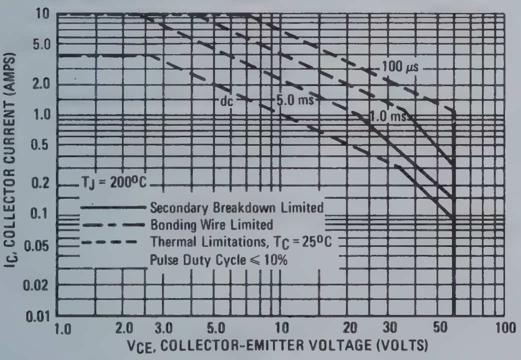
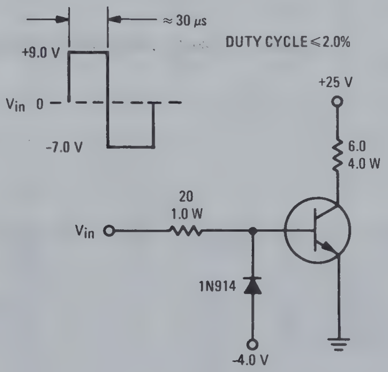


FIGURE 3 – SWITCHING TIME TEST CIRCUIT



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C–V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 2 is based on $T_{J(pk)}$ = 200°C; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leq$ 200°C. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415)

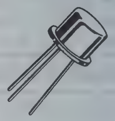
2N4890 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for applications in audio-output feedback control, and general, medium-current switching and amplifier circuits.

- Direct Complement to NPN 2N3053
- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)}$ = 0.12 Vdc (Typ) @ I_C = 150 mAdc
- High Current-Gain—Bandwidth Product — f_T = 280 (Typ) @ I_C = 50 mAdc

PNP SILICON SWITCHING AND AMPLIFIER TRANSISTOR



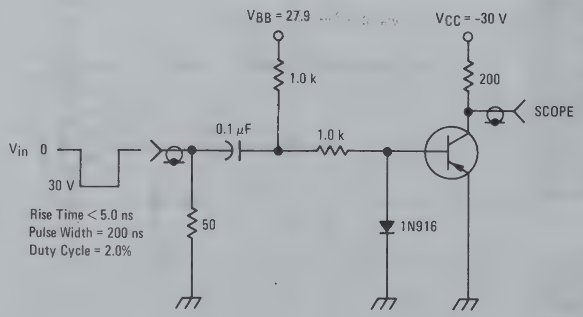
*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	500 700**	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.7	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

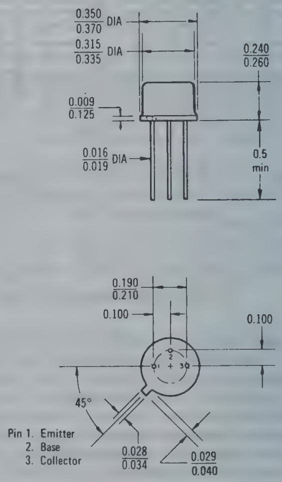
*Indicates JEDEC Registered Data.

**Motorola Guarantees this Data in Addition to JEDEC Registered Data.

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT


VBB = 27.9
VCC = -30 V
1.0 k
200
SCOPE
0.1 µF
1.0 k
Vin 0
30 V
Rise Time < 5.0 ns
Pulse Width = 200 ns
Duty Cycle = 2.0%
50
1N916

SCOPE CHARACTERISTICS
IMPEDANCE 10 MEG MIN
CAPACITANCE 7.0 pF MAX


0.350
0.370
DIA
0.315
0.335
DIA
0.240
0.260
0.009
0.125
0.016
0.019
DIA
0.5
min
0.190
0.210
0.100
0.100
45°
Pin 1. Emitter
2. Base
3. Collector
0.028
0.034
0.029
0.040

CASE 79 (1)
(TO-39)

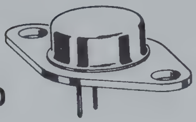
*ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (Note 1) (I_C = 100 μAdc, I_B = 0)	BV_{CEO}	40	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, R_{BE} = 10 ohms)	BV_{CER}	50	–	–	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	–	–	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	I_{CEX}	–	–	0.25	μAdc
Base Cutoff Current (V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	I_{BL}	–	–	0.25	μAdc
ON CHARACTERISTICS					
DC Current Gain (Note 1)	h_{FE}				–
(I_C = 150 mAdc, V_{CE} = 2.5 Vdc)		25	130	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)		50	140	250	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	–	0.12	1.4	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	–	0.82	1.7	Vdc
Base-Emitter On Voltage (I_C = 150 mAdc, V_{CE} = 2.5 Vdc)	$V_{BE(on)}$	–	0.74	1.7	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	100	280	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	–	9.0	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	–	60	80	pF
SWITCHING CHARACTERISTICS					
Delay Time (V_{CC} = 30 Vdc, $V_{BE(off)}$ = 0.8 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 1)	t_d	–	15	50	ns
Rise Time	t_r	–	20	50	ns
Storage Time (V_{CC} = 30 Vdc, I_C = 150 mAdc, $I_{B1} = I_{B2}$ = 15 mAdc) (Figure 1)	t_s	–	110	200	ns
Fall Time	t_f	–	20	70	ns

*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2.0%.

2N4898 thru 2N4900 (SILICON)



CASE 80
(TO-66)

Medium-power PNP silicon transistors designed for driver circuits, switching, and amplifier applications. Complement to NPN 2N4910 thru 2N4912.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4898	2N4899	2N4900	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous *	I_C*	← 1.0 → ← 4.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	← 25 → ← 0.143 →			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

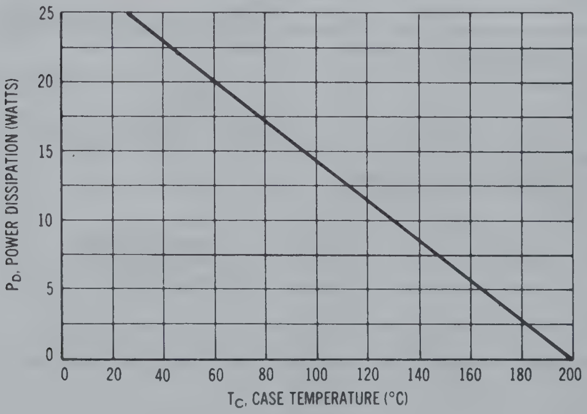
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	7.0	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements.

The 4.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE

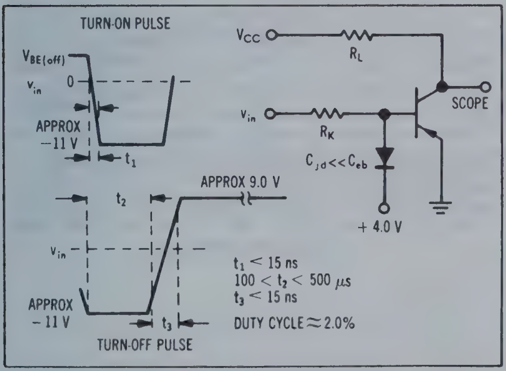


ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage (1) (I_C = 0.1 Adc, I_B = 0)	2N4898 2N4899 2N4900	-	$BV_{CEO(sus)}$	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0) (V_{CE} = 30 Vdc, I_B = 0) (V_{CE} = 40 Vdc, I_B = 0)	 2N4898 2N4899 2N4900		I_{CEO}	 - - -	 0.5 0.5 0.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)		12	I_{CEX}	 - -	 0.1 1.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)		-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS (1)						
DC Current Gain (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)		8	h_{FE}	 40 20 10	 - 100 -	-
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc)		9 11 13	$V_{CE(sat)}$	-	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc)		11 13	$V_{BE(sat)}$	-	1.3	Vdc
Base-Emitter On Voltage (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)		11 13	$V_{BE(on)}$	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C - 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)		-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		-	h_{fe}	25	-	-

(1) Pulse Test: PW ≈300 µs, Duty Cycle ≈ 2.0%

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT



TURN-ON PULSE
$V_{BE(off)}$
V_{in}
0
APPROX −11 V
t_1
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
+ 4.0 V
t_2
APPROX 9.0 V
V_{in}
APPROX − 11 V
t_3
TURN-OFF PULSE
t_1 < 15 ns
100 < t_2 < 500 µs
t_3 < 15 ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

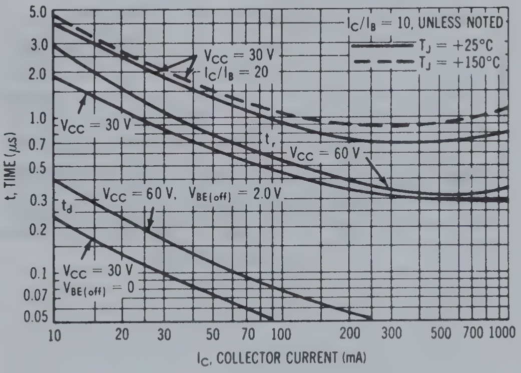


FIGURE 4 — THERMAL RESPONSE

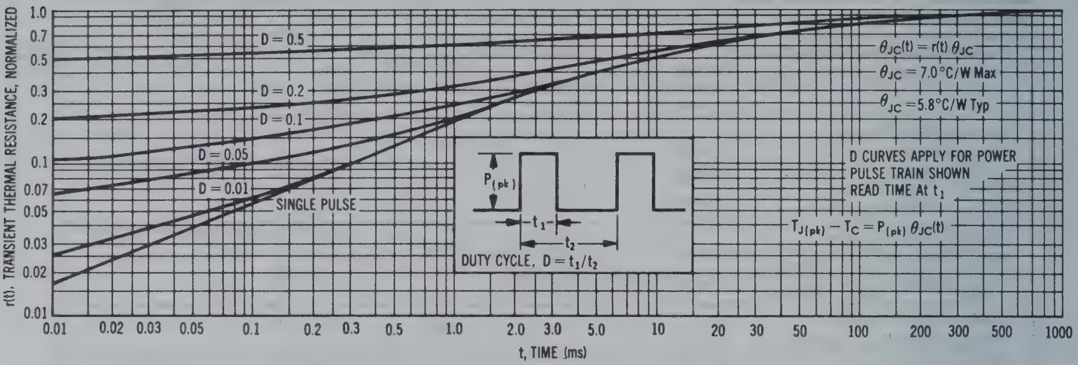
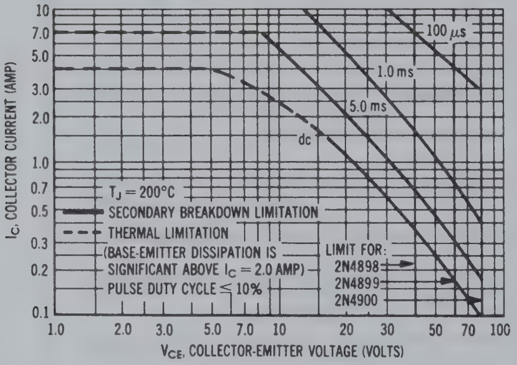


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor which must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 5 is based upon $T_{J(pk)} = 200°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power which can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

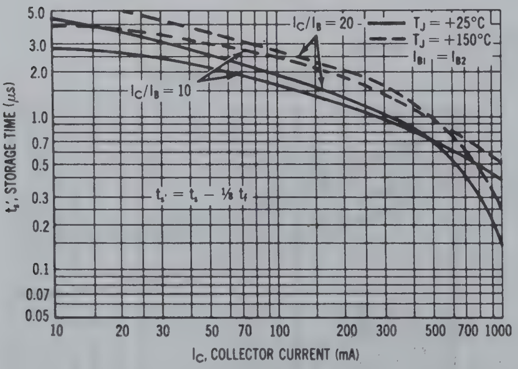


FIGURE 7 — FALL TIME

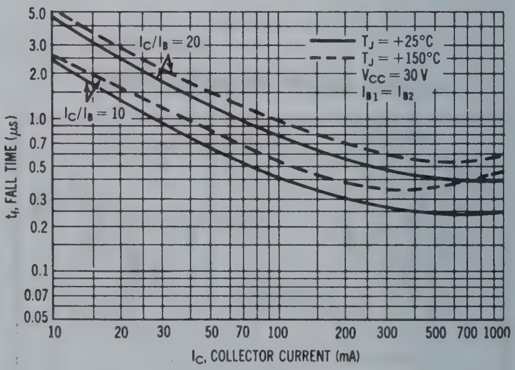


FIGURE 8 — CURRENT GAIN

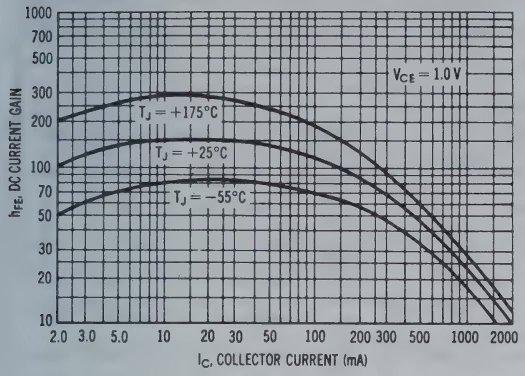


FIGURE 9 — COLLECTOR SATURATION REGION

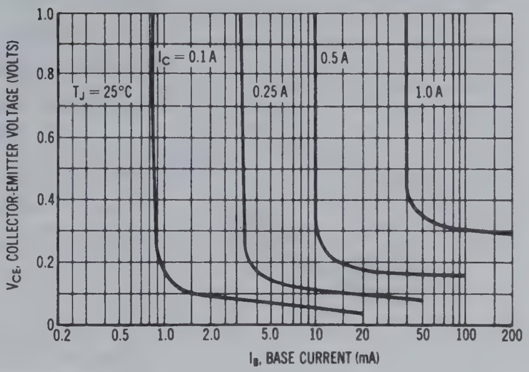


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

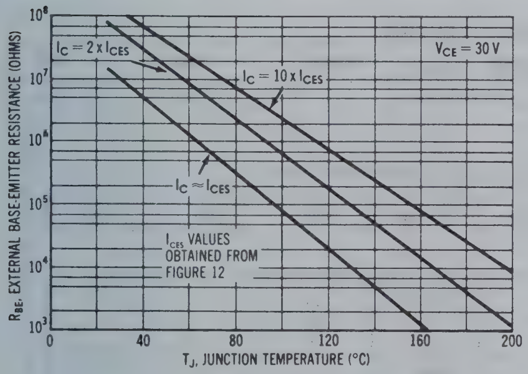


FIGURE 11 — "ON" VOLTAGE

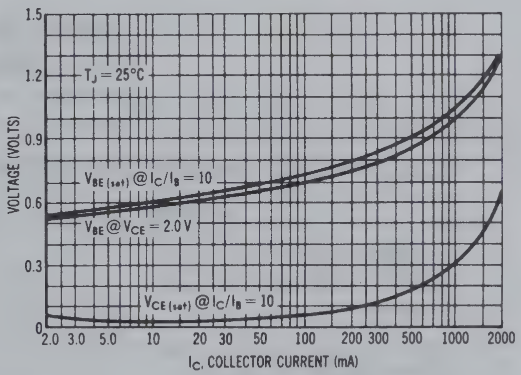


FIGURE 12 — COLLECTOR CUTOFF REGION

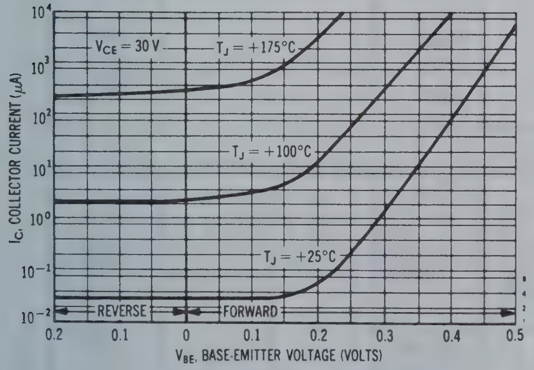
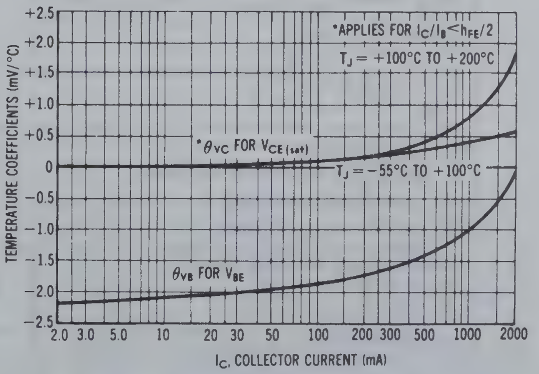
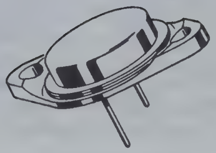


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4901 (SILICON)
2N4902
2N4903

PNP power transistors for use in power amplifier and switching circuits. Complement to NPN 2N5067, 2N5068, 2N5069.



CASE 11
(TO-3)

MAXIMUM RATINGS

Rating	Symbol	2N4901	2N4902	2N4903	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous	I_C	← 5.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$	P_D	← 87.5 →			Watts
Derate above 25°C		← 0.5 →			W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* ($I_C = 0.2$ Adc, $I_B = 0$) 2N4901 2N4902 2N4903	11	$V_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	0.1 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)		I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* ($I_C = 1.0$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 5.0$ Adc, $V_{CE} = 2.0$ Vdc)	1	h_{FE}*	20 7.0	80 -	-
Collector-Emitter Saturation Voltage* ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc ($I_C = 5.0$ Adc, $I_B = 1.0$ Adc)	2, 3, 4	$V_{CE(sat)}$*	- -	0.4 1.5	Vdc
Base-Emitter On Voltage* ($I_C = 1.0$ Adc, $V_{CE} = 2.0$ Vdc)	3, 4	$V_{BE(on)}$*	-	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product ($I_C = 1.0$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain ($I_C = 0.5$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)		h_{fe}	20	-	-

* Pulse Test: PW = 300 μs, Duty Cycle ≈ 2.0%

FIGURE 1 — NORMALIZED DC CURRENT GAIN

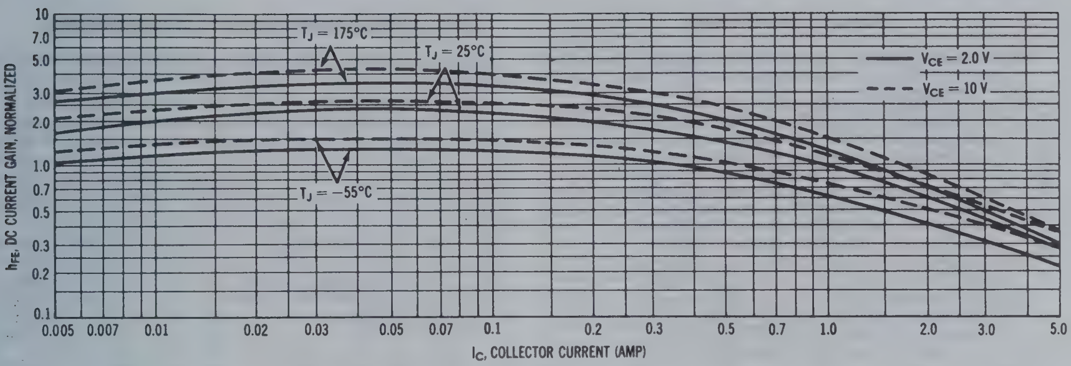


FIGURE 2 — COLLECTOR SATURATION REGION

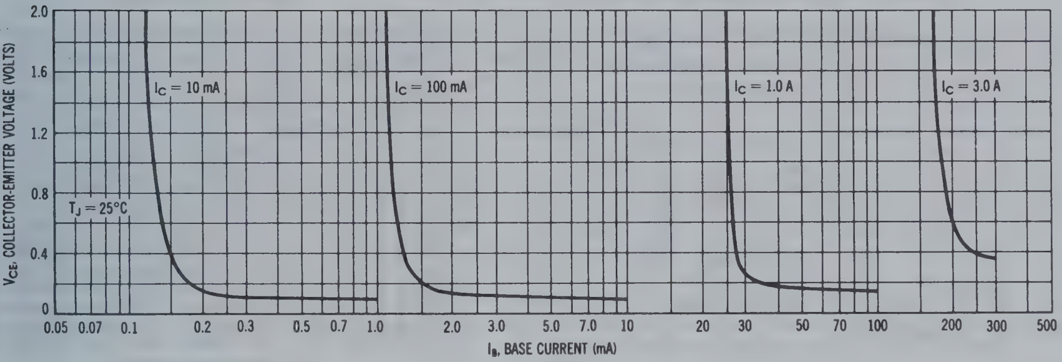


FIGURE 3 — "ON" VOLTAGE

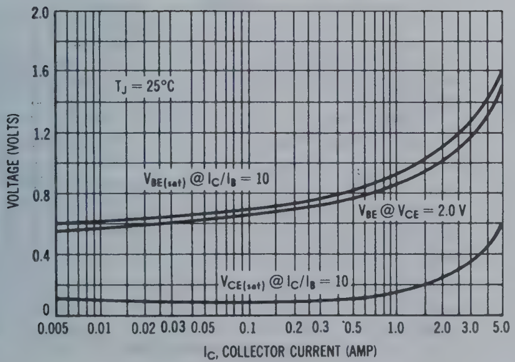
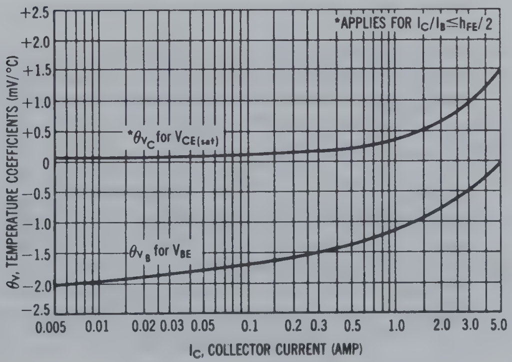


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

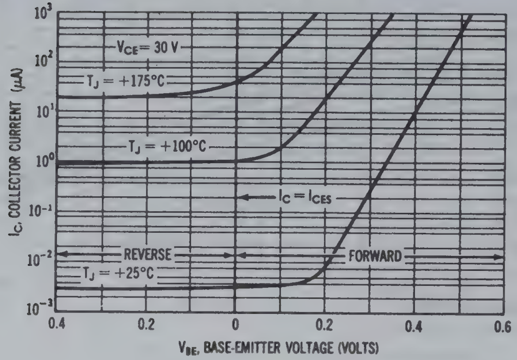


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

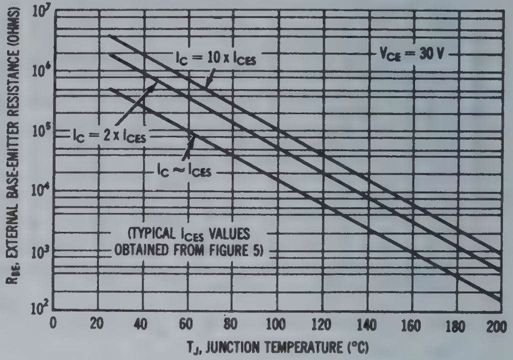


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

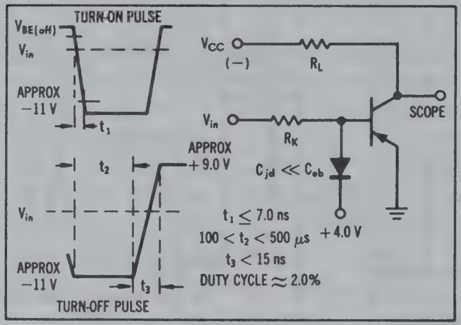

$V_{BE(off)}$
TURN-ON PULSE
V_{in}
APPROX −11 V
t_1
t_2
APPROX +9.0 V
V_{in}
APPROX −11 V
t_3
TURN-OFF PULSE
V_{CC} (−)
R_L
SCOPE
V_{in}
R_K
$C_{jd} \ll C_{eb}$
+4.0 V
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 8 — CAPACITANCE

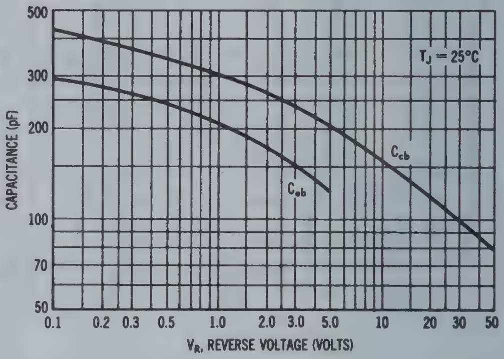


FIGURE 9 — TURN-ON TIME

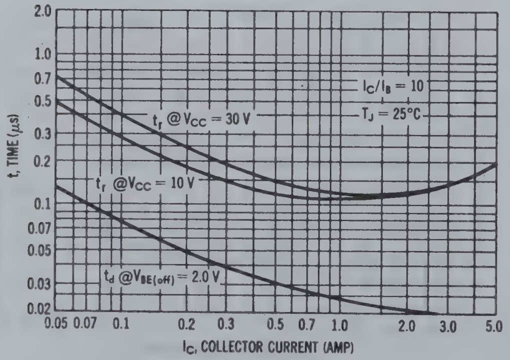
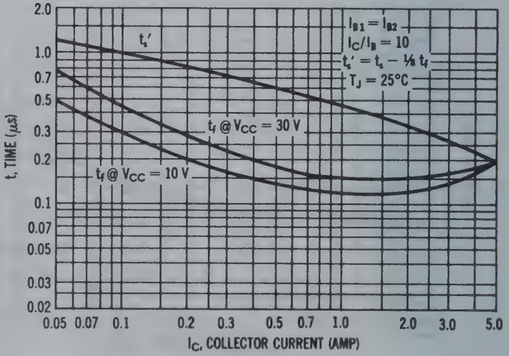
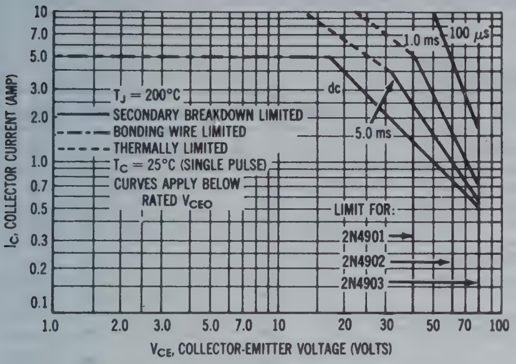


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

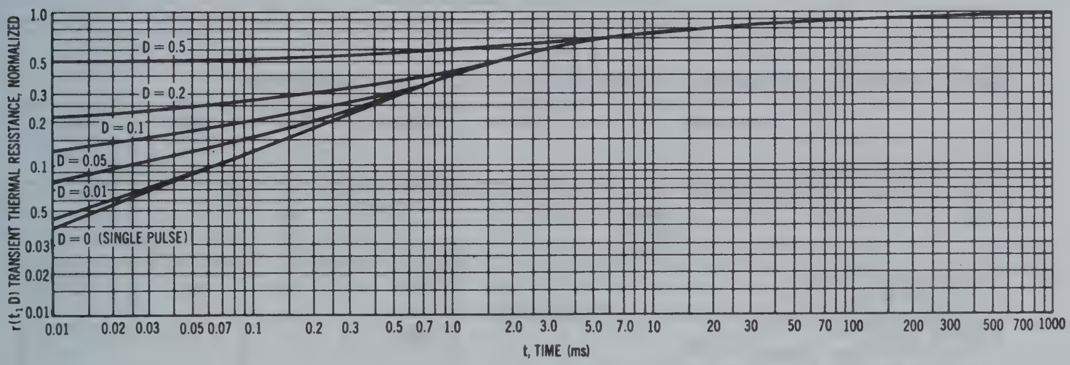
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

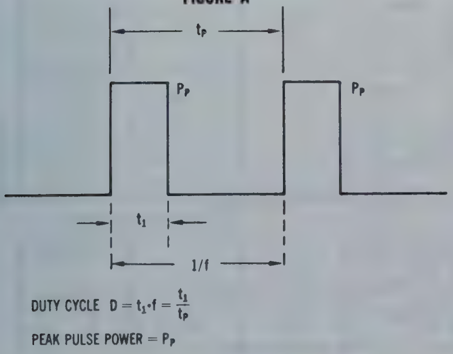
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:
The 2N4901 is dissipating 100 watts under the following conditions:
$t_1 = 0.1$ ms, $t_P = 0.5$ ms. (D = 0.2)

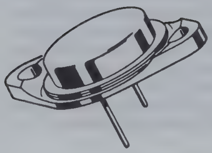
Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of r (t_1, D) is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.27 \times 100 \times 2.0 = 54°C$$

2N4904 (SILICON)
2N4905
2N4906

PNP power transistors for use in power amplifier and switching circuits. Complement to NPN 2N4913 thru 2N4915.



CASE 11
(TO-3)

MAXIMUM RATINGS

Rating	Symbol	2N4904	2N4905	2N4906	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous	I_C	← 5.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	← 87.5 → ← 0.5 →			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) ($I_C = 0.2$ Adc, $I_B = 0$) 2N4904 2N4905 2N4906	11	$V_{CEO(sus)}$	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	0.1 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)		I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS (1)					
DC Current Gain ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 5.0$ Adc, $V_{CE} = 2.0$ Vdc)	1	h_{FE}	25 7.0	100 -	-
Collector-Emitter Saturation Voltage ($I_C = 2.5$ Adc, $I_B = 0.25$ Adc) ($I_C = 5.0$ Adc, $I_B = 1.0$ Adc)	2, 3, 4	$V_{CE(sat)}$	- -	1.0 1.5	Vdc
Base-Emitter On Voltage ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc)	3, 4	$V_{BE(on)}$	-	1.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product ($I_C = 1.0$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain ($I_C = 0.5$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)		h_{fe}	40	-	

(1) Pulse Test: PW = 300 μs, Duty Cycle ≈ 2.0%

2N4904, 2N4905, 2N4906 (continued)

FIGURE 1 — NORMALIZED DC CURRENT GAIN

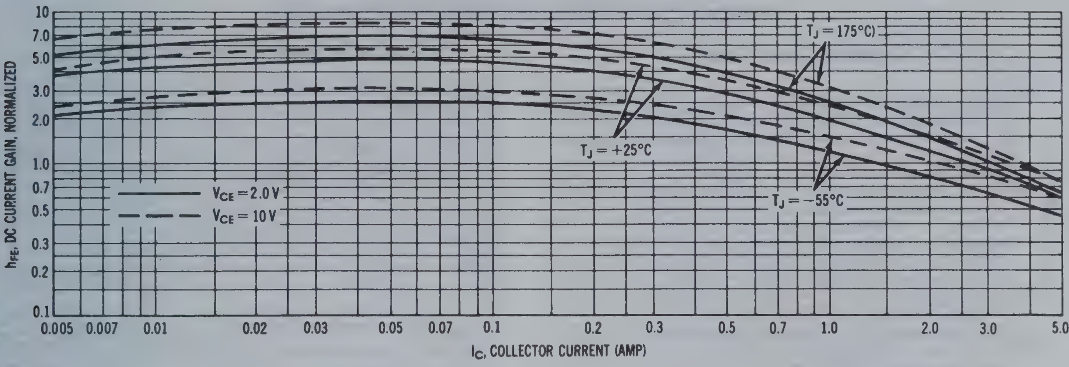


FIGURE 2 — COLLECTOR SATURATION REGION

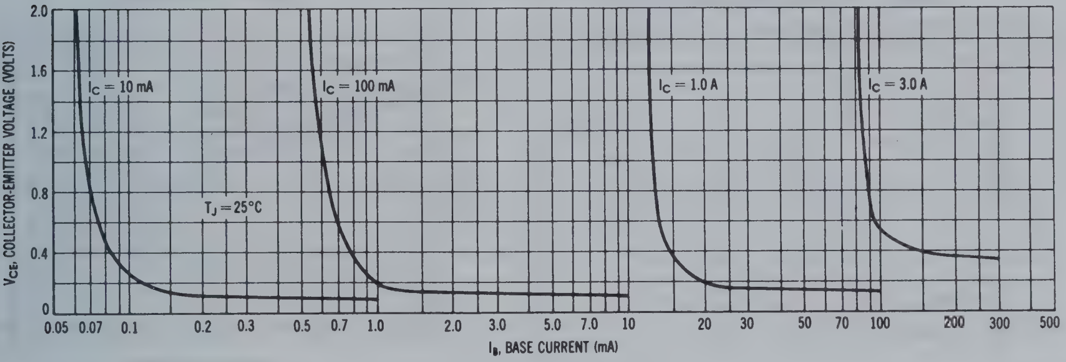


FIGURE 3 — "ON" VOLTAGE

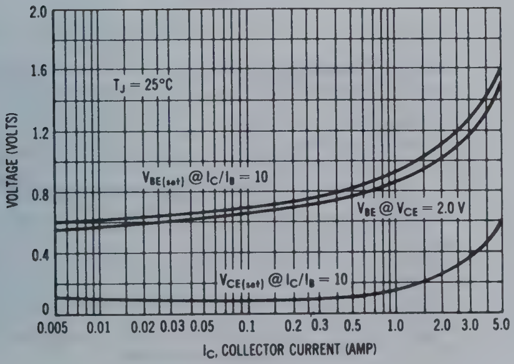
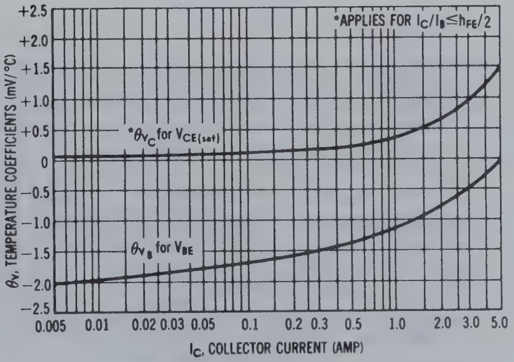


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

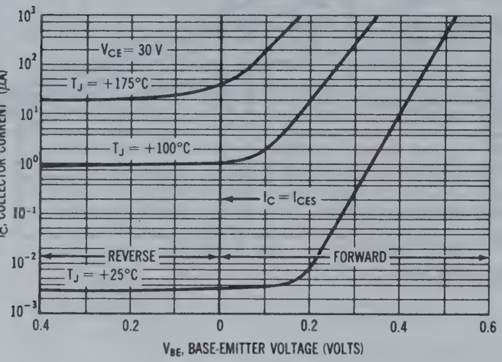


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

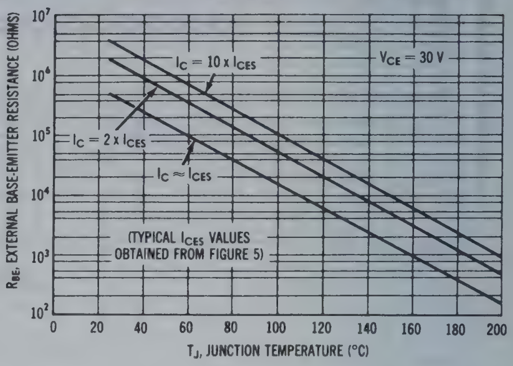


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

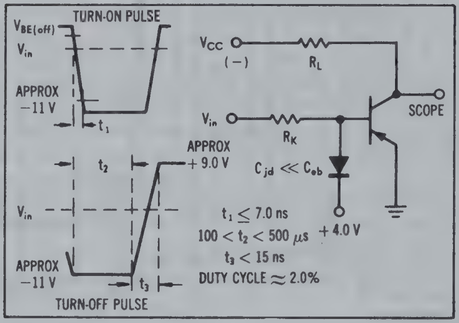

$V_{BE(off)}$
TURN-ON PULSE
V_{in}
APPROX −11 V
t_1
t_2
APPROX +9.0 V
V_{in}
APPROX −11 V
t_3
TURN-OFF PULSE
V_{CC} (−)
R_L
V_{in}
R_K
SCOPE
$C_{jd} \ll C_{eb}$
+4.0 V
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 8 — CAPACITANCE

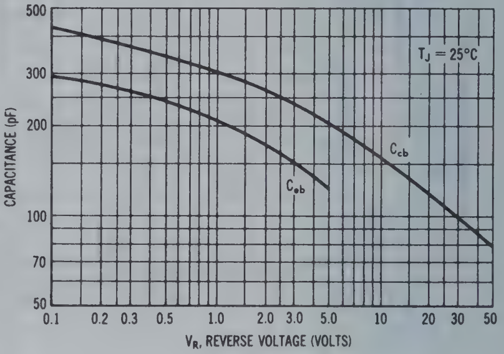


FIGURE 9 — TURN-ON TIME

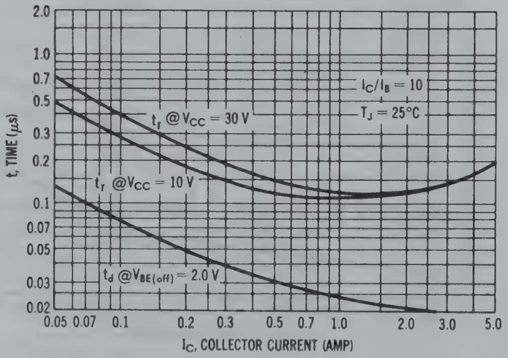
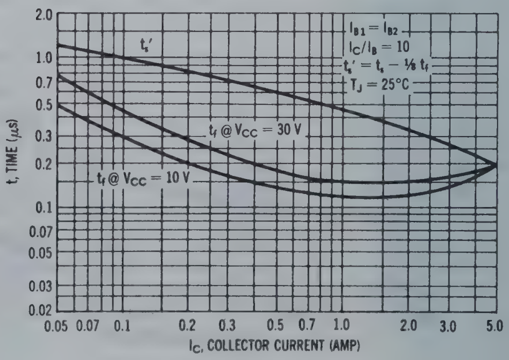
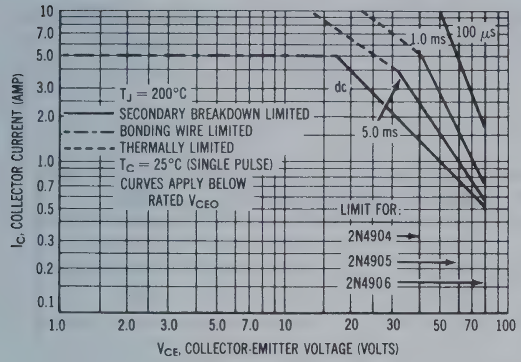


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

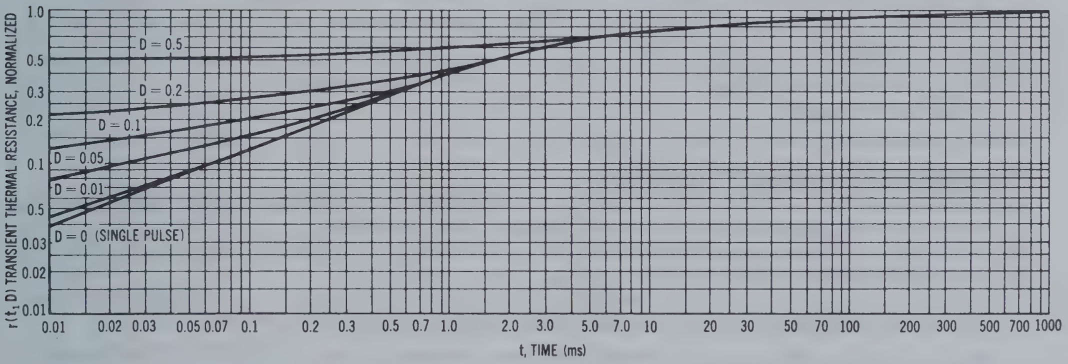
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

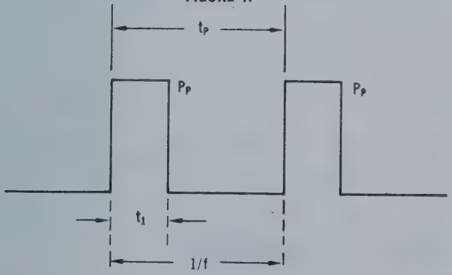
The data of Figure 11 is based on $T_{J(pk)}$ = 200°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 \cdot f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

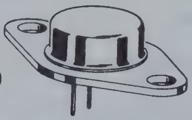
The 2N4904 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_P = 0.5$ ms. $(D = 0.2)$

Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.27 \times 100 \times 2.0 = 54°C$$

2N4910 thru 2N4912 (SILICON)



CASE 80
(TO-66)

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications. Complement to PNP 2N4898 thru 2N4900.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4910	2N4911	2N4912	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous*	I_C*	← 1.0 → ← 4.0 →			Adc
Base Current — Continuous	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$	P_D	← 25 →			Watts
Derate above 25°C		← 0.143 →			mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

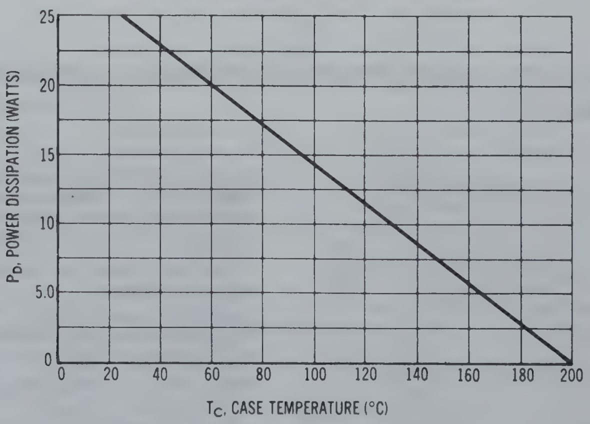
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	7.0	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements.

The 4.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 0.1 Adc, I_B = 0)	-	$BV_{CEO(sus)}$			Vdc
2N4910			40	-	
2N4911			60	-	
2N4912			80	-	
Collector Cutoff Current	-	I_{CEO}			mAdc
(V_{CE} = 20 Vdc, I_B = 0) 2N4910			-	0.5	
(V_{CE} = 30 Vdc, I_B = 0) 2N4911			-	0.5	
(V_{CE} = 40 Vdc, I_B = 0) 2N4912			-	0.5	
Collector Cutoff Current	12	I_{CEX}			mAdc
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc)			-	0.1	
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)			-	1.0	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS (1)					
DC Current Gain	8	h_{FE}			-
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			40	-	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)			20	100	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)			10	-	
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc)	9 11 13	$V_{CE(sat)}$	-	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.1 Adc)	11 13	$V_{BE(sat)}$	-	1.3	Vdc
Base-Emitter On Voltage (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	11 13	$V_{BE(on)}$	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	25	-	

(1) Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

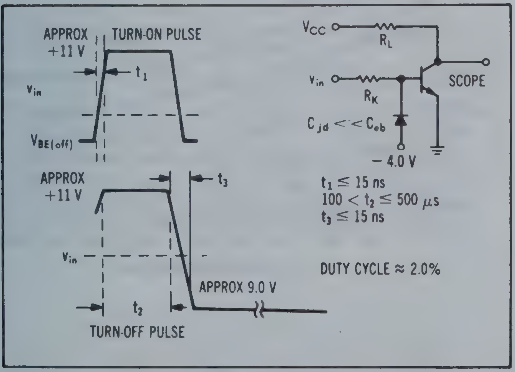

APPROX +11 V
TURN-ON PULSE
t_1
v_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
v_{in}
APPROX 9.0 V
t_2
TURN-OFF PULSE
V_{CC}
R_L
v_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
−4.0 V
$t_1 \leq$ 15 ns
$100 < t_2 \leq 500$ μs
$t_3 \leq$ 15 ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

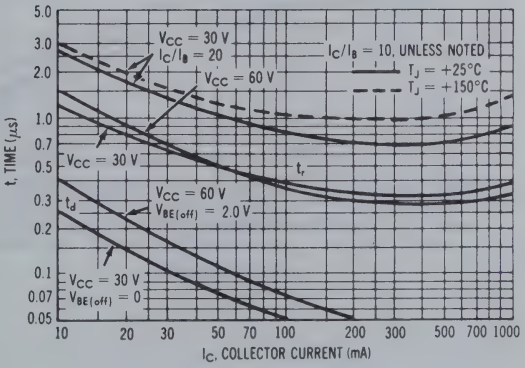


FIGURE 4 — THERMAL RESPONSE

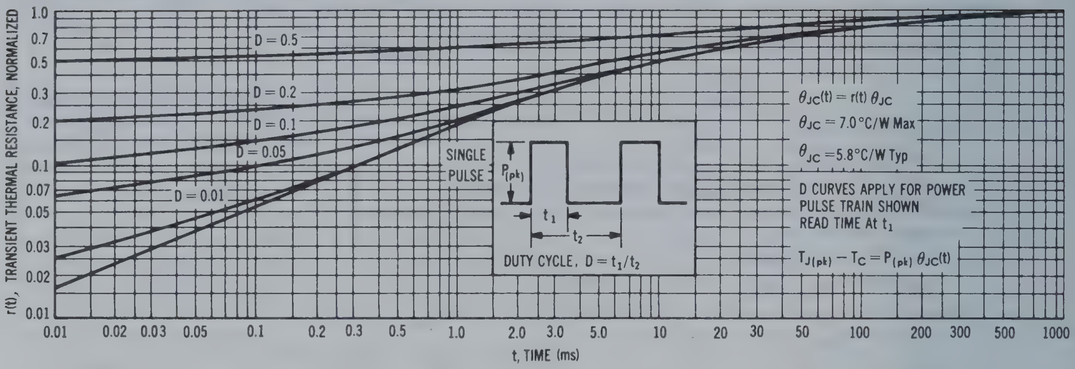
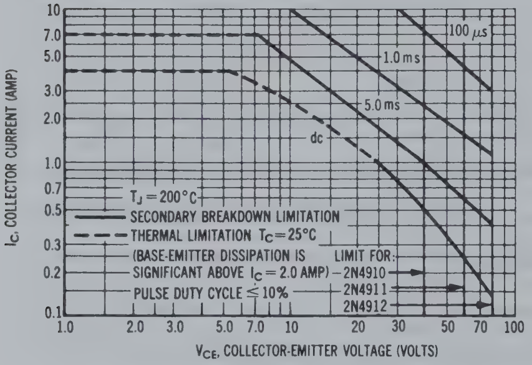


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

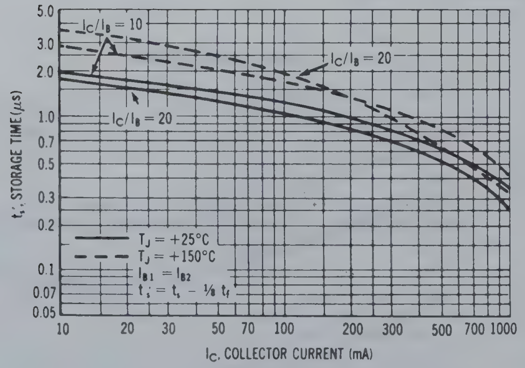
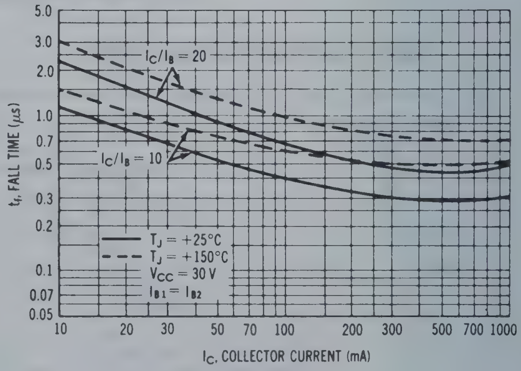


FIGURE 7 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 8 — CURRENT GAIN

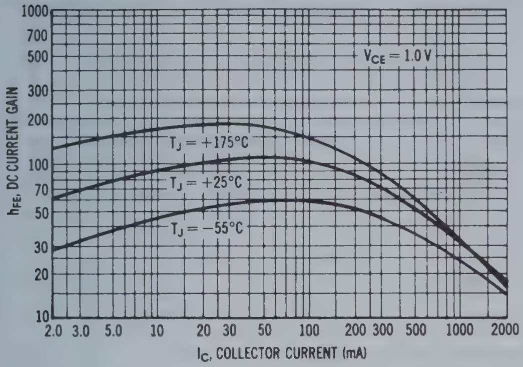


FIGURE 9 — COLLECTOR SATURATION REGION

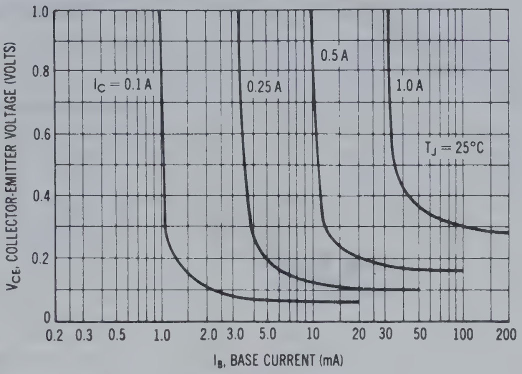


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

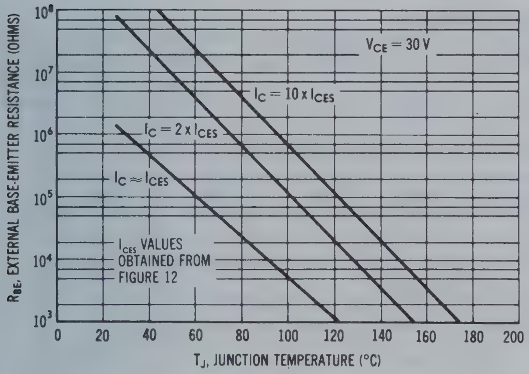


FIGURE 11 — "ON" VOLTAGE

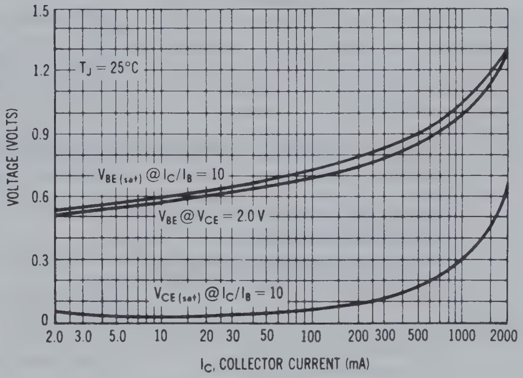


FIGURE 12 — COLLECTOR CUTOFF REGION

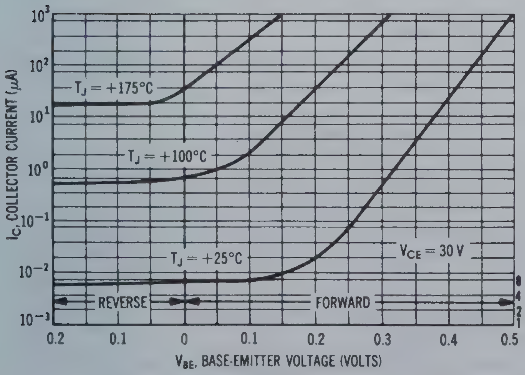
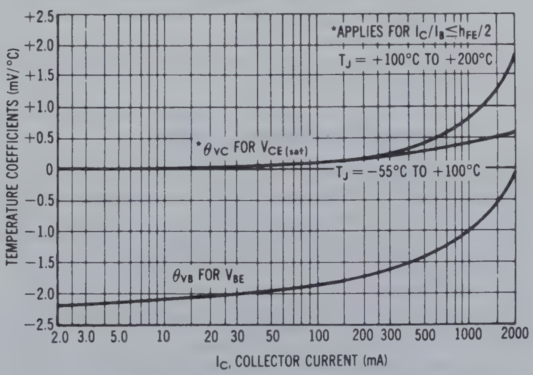
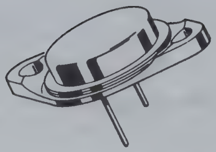


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4913 (SILICON)
2N4914
2N4915

NPN power transistors for use in power amplifier and switching circuits. Complement to PNP 2N4904 thru 2N4906.



CASE 11
(TO-3)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4913	2N4914	2N4915	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous	I_C	5.0			Adc
Base Current - Continuous	I_B	1.0			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	87.5 0.5			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) ($I_C = 0.2$ Adc, $I_B = 0$) 2N4913 2N2914 2N4915	11	$BV_{CEO(sus)}$	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	1.0 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)	5, 6	I_{CBO}	-	1.0	mAdc
Emitter Cutoff Current ($V_{EB} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS (1)					
DC Current Gain ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 5.0$ Adc, $V_{CE} = 2.0$ Vdc)	1	h_{FE}	25 7.0	100 -	-
Collector-Emitter Saturation Voltage ($I_C = 2.5$ Adc, $I_B = 250$ mAdc) ($I_C = 5.0$ Adc, $I_B = 1.0$ Adc)	2, 3, 4	$V_{CE(sat)}$	- -	1.0 1.5	Vdc
Base-Emitter On Voltage ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc)	3, 4	$V_{BE(on)}$	-	1.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product ($I_C = 1.0$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain ($I_C = 500$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)		h_{fe}	20	-	-

(1) Pulse Test, PW ≈300 µs, Duty Cycle ≈ 2.0%

FIGURE 1 — NORMALIZED DC CURRENT GAIN

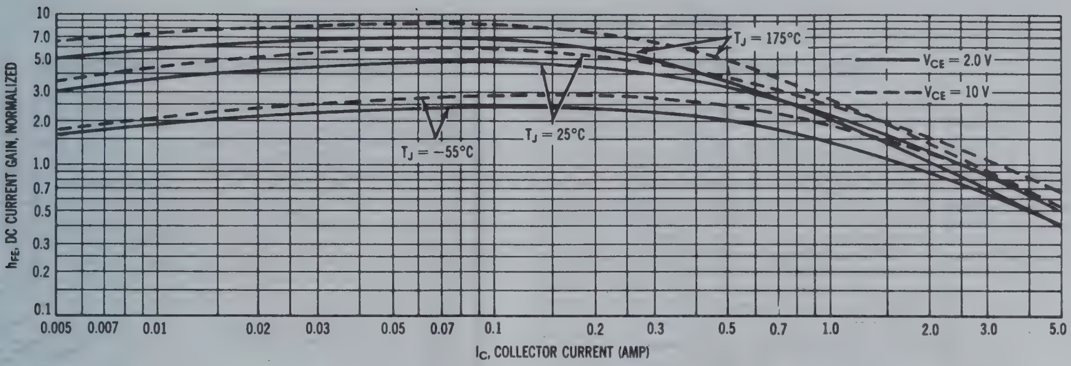


FIGURE 2 — COLLECTOR SATURATION REGION

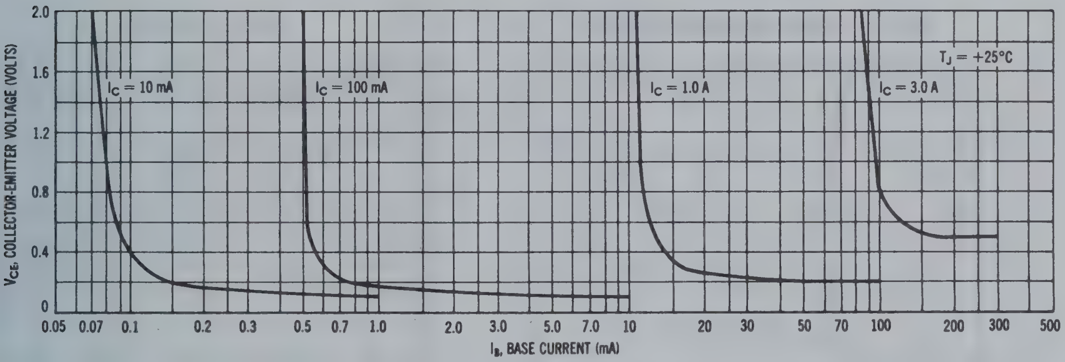


FIGURE 3 — "ON" VOLTAGES

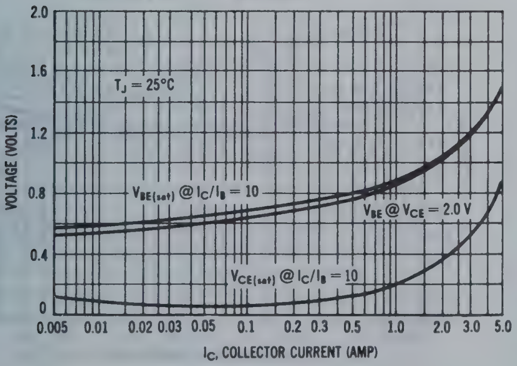
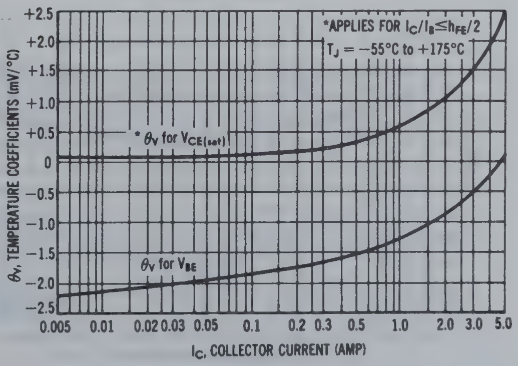


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

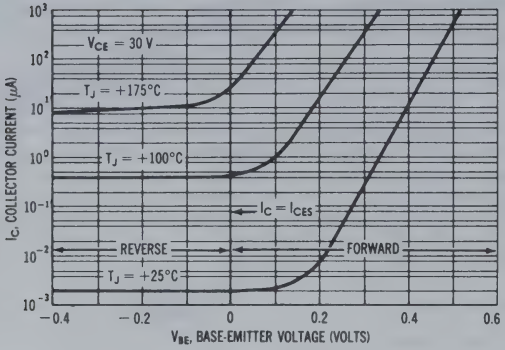


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

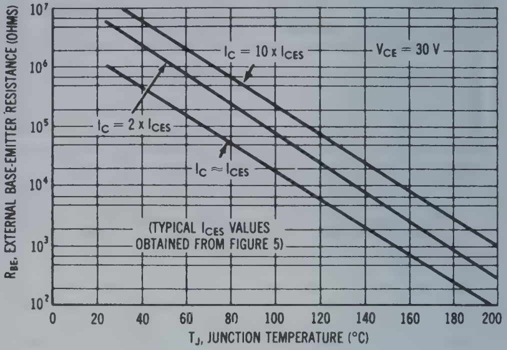


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

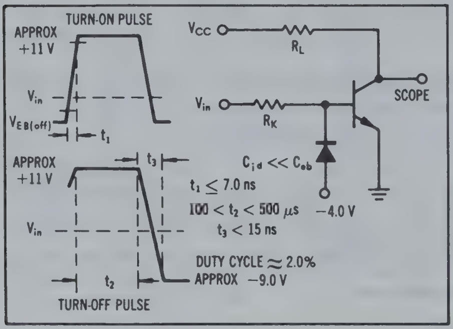

TURN-ON PULSE
APPROX +11 V
V_{in}
$V_{EB(off)}$
t_1
APPROX +11 V
t_3
V_{in}
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
−4.0 V
DUTY CYCLE ≈ 2.0%
APPROX −9.0 V

FIGURE 8 — CAPACITANCE

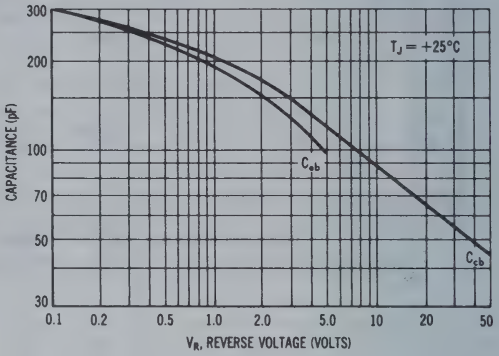


FIGURE 9 — TURN-ON TIME

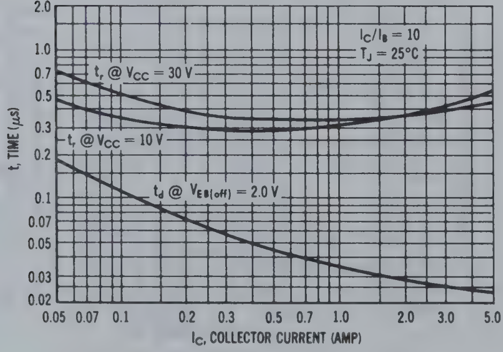
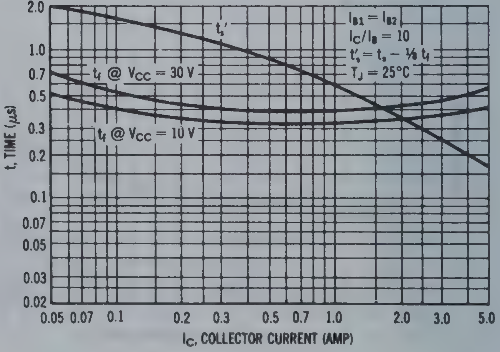
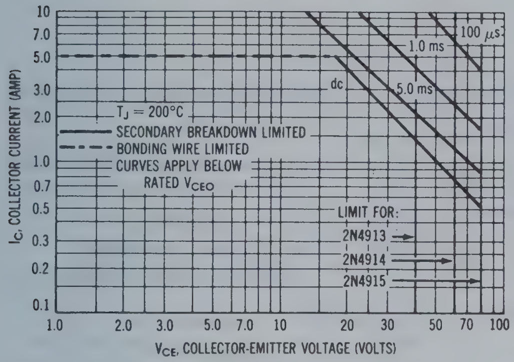


FIGURE 10 — TURN-OFF TIME



RATİNG AND THERMAL DATA

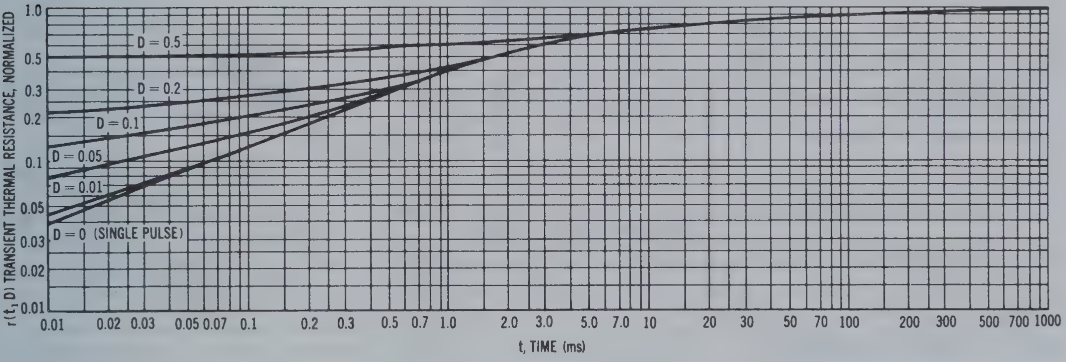
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

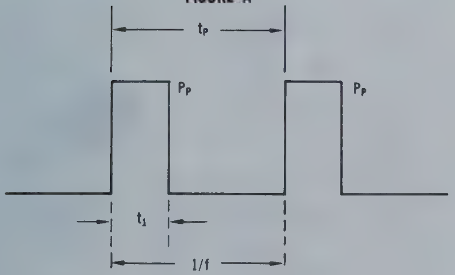
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 \cdot f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

The 2N4913 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_P = 0.5$ ms. $(D = 0.2)$

Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.28.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.28 \times 100 \times 2.0 = 56°C$$

2N4918 thru 2N4920 (SILICON)
MJE4918 thru MJE4920

MEDIUM-POWER PLASTIC PNP SILICON TRANSISTORS

. . . designed for driver circuits, switching, and amplifier applications. These high-performance plastic devices feature:

- Low Saturation Voltage — $V_{CE(sat)}$ = 0.6 Vdc (Max) @ I_C = 1.0 Amp
- Excellent Power Dissipation Due to Thermopad Construction — P_D = 30 and 40 W @ T_C = 25°C
- Excellent Safe Operating Area
- Gain Specified to I_C = 1.0 Amp
- Complement to NPN 2N4921, 2N4922, 2N4923 and MJE4921, MJE4922, MJE4923
- Choice of Packages — 2N4918 thru 2N4920, 30 Watts, Case 77
  MJE4918 thru MJE4920, 40 Watts, Case 199

3 AMPERE
GENERAL-PURPOSE
POWER TRANSISTORS

40-80 VOLTS
30 and 40 WATTS

*MAXIMUM RATINGS

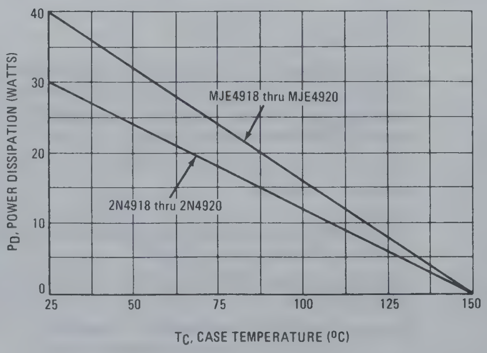
Ratings	Symbol	2N4918 MJE4918	2N4919 MJE4919	2N4920 MJE4920	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous (1)	I_C*	← 1.0 → ← 3.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
		2N4918 series	**MJE4918 series**		
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	30 0.24	40 0.32		Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← −65 to +150 →			°C

THERMAL CHARACTERISTICS (2)

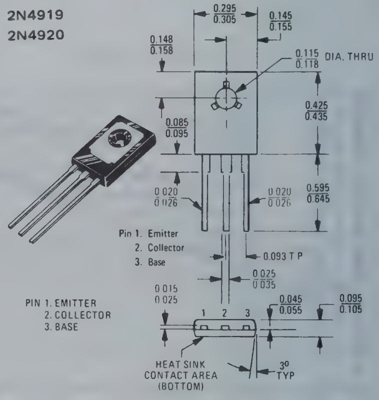
Characteristic	Symbol	2N4918/20	MJE4918/20	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.16	3.125	°C/W

*Indicates JEDEC Registered Data for 2N4918 Series
(1) The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 3.0 Amp maximum value is based upon actual current-handling capability of the device (See Figure 5).
(2) Recommend use of thermal compound for lowest thermal resistance.

FIGURE 1 — POWER DERATING

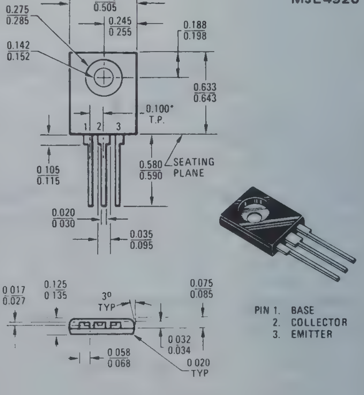


2N4918
2N4919
2N4920


0.295
0.305
0.145
0.155
0.148
0.158
0.115
0.118
DIA. THRU
0.425
0.435
0.085
0.095
0.020
0.026
0.020
0.026
0.595
0.645
Pin 1. Emitter
2. Collector
3. Base
0.093 T P
0.025
0.035
0.015
0.025
PIN 1. EMITTER
2. COLLECTOR
3. BASE
1
2
3
0.045
0.055
0.095
0.105
HEAT SINK
CONTACT AREA
(BOTTOM)
3°
TYP

CASE 77-03

MJE4918
MJE4919
MJE4920


0.495
0.505
0.275
0.285
0.245
0.255
0.188
0.198
0.142
0.152
0.633
0.643
0.100*
T.P.
1
2
3
0.105
0.115
0.580
0.590
SEATING
PLANE
0.020
0.030
0.035
0.095
0.017
0.027
0.125
0.135
3°
TYP
0.075
0.085
0.032
0.034
0.058
0.068
0.020
TYP
PIN 1. BASE
2. COLLECTOR
3. EMITTER

*Dimension is to centerline of leads

CASE 199-04

ELECTRICAL CHARACTERISTICS ($T_C = 25^oC$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) ($I_C = 0.1$ Adc, $I_B = 0$) 2N4918,MJE4918 2N4919,MJE4919 2N4920,MJE4920	–	$V_{CEO(sus)}$	40 60 80	– – –	Vdc
Collector Cutoff Current ($V_{CE} = 20$ Vdc, $I_B = 0$) 2N4918,MJE4918 ($V_{CE} = 30$ Vdc, $I_B = 0$) 2N4919,MJE4919 ($V_{CE} = 40$ Vdc, $I_B = 0$) 2N4920,MJE4920	–	I_{CEO}	– – –	0.5 0.5 0.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc, $T_C = 125^oC$)	13	I_{CEX}	– –	0.1 0.5	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)	–	I_{CBO}	–	0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0$ Vdc, $I_C = 0$)	–	I_{EBO}	–	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain (1) ($I_C = 50$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 500$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)	9	h_{FE}	40 20 10	– 100 –	–
Collector-Emitter Saturation Voltage (1) ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc)	10 12 14	$V_{CE(sat)}$	–	0.6	Vdc
Base-Emitter Saturation Voltage (1) ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc)	12 14	$V_{BE(sat)}$	–	1.3	Vdc
Base-Emitter On Voltage (1) ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)	12 14	$V_{BE(on)}$	–	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product ($I_C = 250$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)	–	f_T	3.0	–	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	–	C_{ob}	–	100	pF
Small-Signal Current Gain ($I_C = 250$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	–	h_{fe}	25	–	–

*Indicates JEDEC Registered Data for 2N4918 Series.

(1) Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

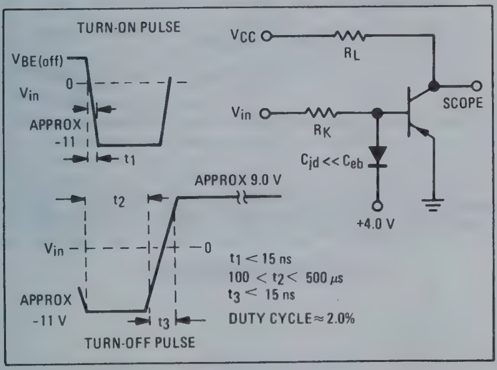

TURN-ON PULSE
$V_{BE(off)}$
V_{in}
0
APPROX -11
t_1
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
+4.0 V
APPROX 9.0 V
t_2
V_{in}
0
APPROX -11 V
t_3
TURN-OFF PULSE
$t_1 < 15$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

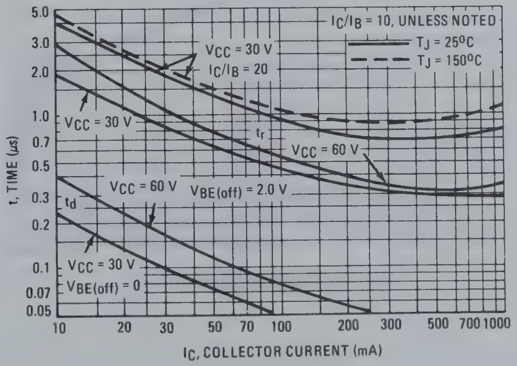
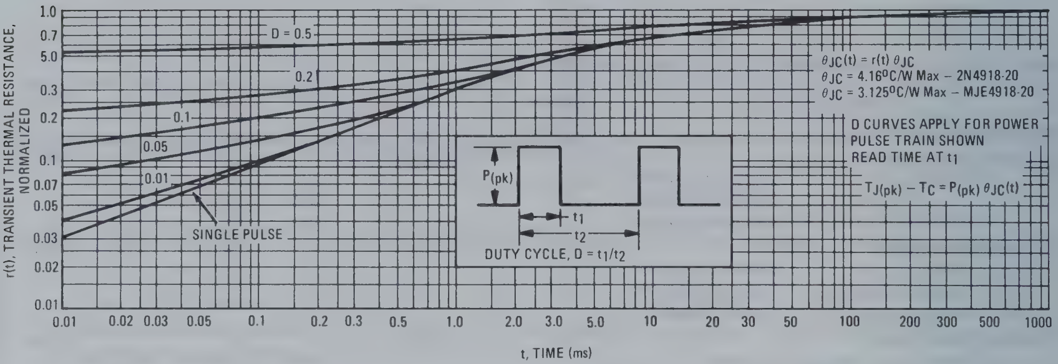


FIGURE 4 — THERMAL RESPONSE



ACTIVE-REGION SAFE OPERATING AREA

FIGURE 5 — 2N4918 thru 2N4920

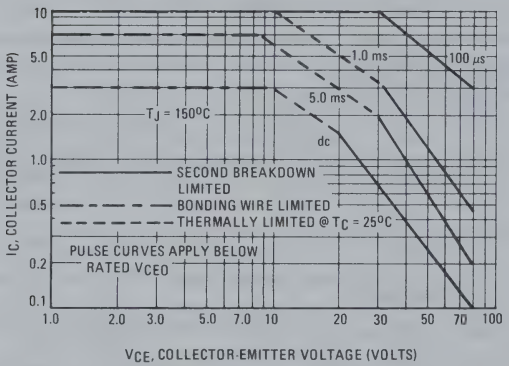
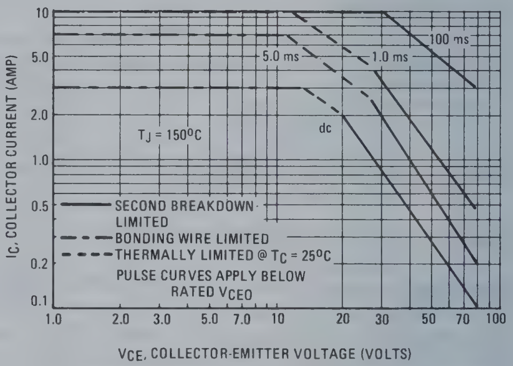


FIGURE 6 — MJE4918 thru MJE4920



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C - V_{CE} operation i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figures 5 and 6 is based on $T_{J(pk)} = 150^{\circ}C$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leq 150^{\circ}C$. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415)

FIGURE 7 — STORAGE TIME

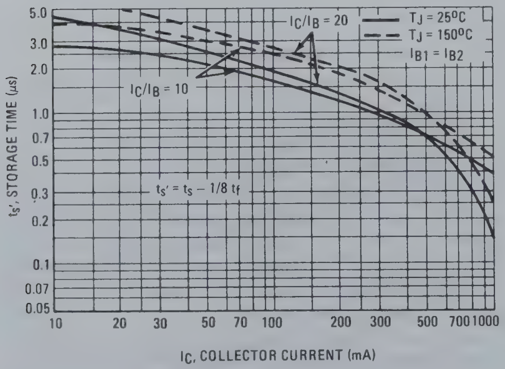
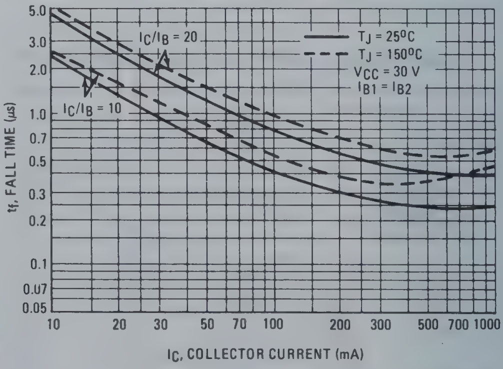


FIGURE 8 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 9 – CURRENT GAIN

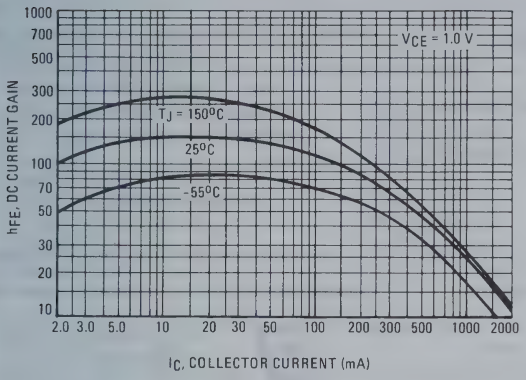


FIGURE 10 – COLLECTOR SATURATION REGION

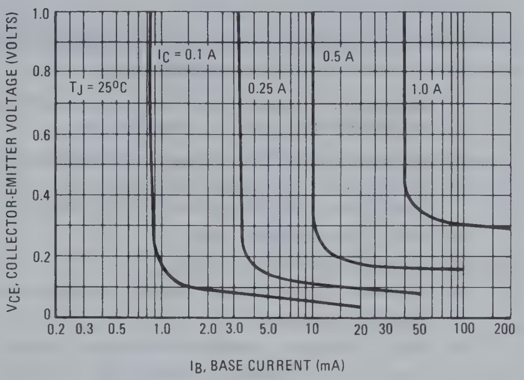


FIGURE 11 – EFFECTS OF BASE-EMITTER RESISTANCE

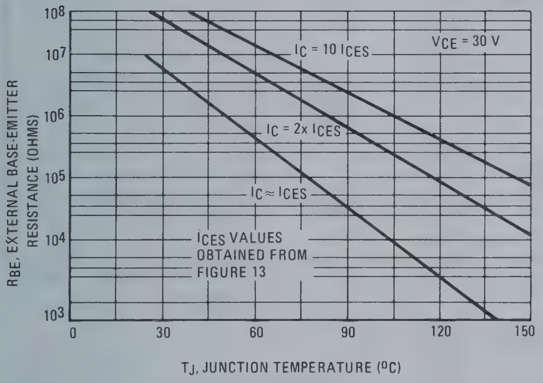


FIGURE 12 – "ON" VOLTAGE

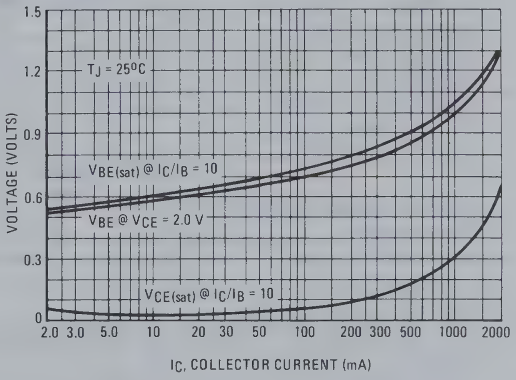


FIGURE 13 – COLLECTOR CUTOFF REGION

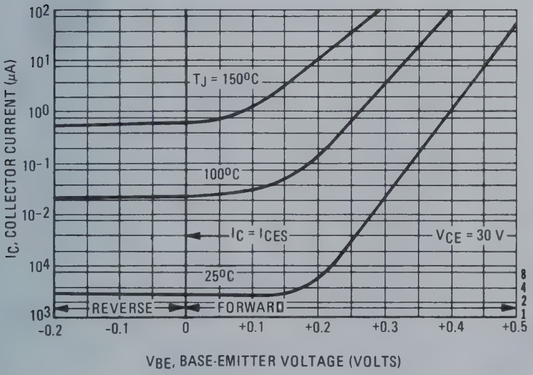
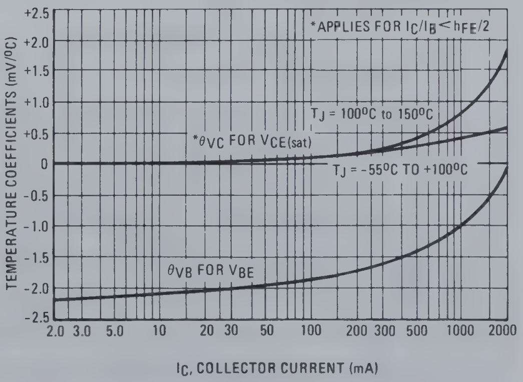


FIGURE 14 – TEMPERATURE COEFFICIENTS



2N4921 thru 2N4923 (SILICON)
MJE4921 thru MJE4923

MEDIUM-POWER PLASTIC NPN SILICON TRANSISTORS

. . . designed for driver circuits, switching, and amplifier applications. These high-performance plastic devices feature:

- Low Saturation Voltage – $V_{CE(sat)}$ = 0.6 Vdc (Max) @ I_C = 1.0 Amp
- Excellent Power Dissipation Due to Thermopad Construction – P_D = 30 and 40 W @ T_C = 25°C
- Excellent Safe Operating Area
- Gain Specified to I_C = 1.0 Amp
- Complement to PNP 2N4918, 2N4919, 2N4920 and MJE4918, MJE4919, MJE4920
- Choice of Packages – 2N4921 thru 2N4923, 30 Watts – Case 77
  MJE4921 thru MJE4923, 40 Watts – Case 199

**3 AMPERE
GENERAL PURPOSE
POWER TRANSISTORS**

**40-80 VOLTS
30 and 40 WATTS**

*MAXIMUM RATINGS

Rating	Symbol	2N4921 MJE4921	2N4922 MJE4922	2N4923 MJE4923	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current – Continuous (1)	I_C	← 1.0 → ← 3.0 →			Adc
Base Current – Continuous	I_B	← 1.0 →			Adc
		2N4921 Series	MJE4921 Series		
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	30 0.24	40 0.32		Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +150 →			°C

THERMAL CHARACTERISTICS (2)

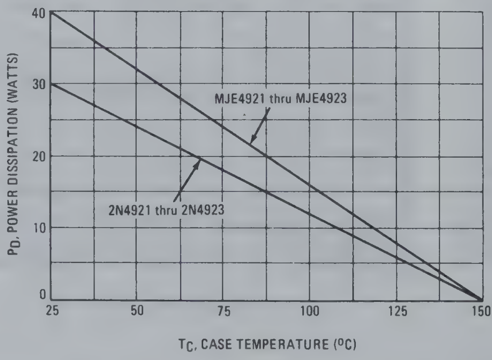
Characteristic	Symbol	2N4921/4923	MJE4921/4923	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.16	3.125	°C/W

(1) The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 3.0 Amp maximum value is based upon actual current-handling capability of the device (see Figures 5 and 6).

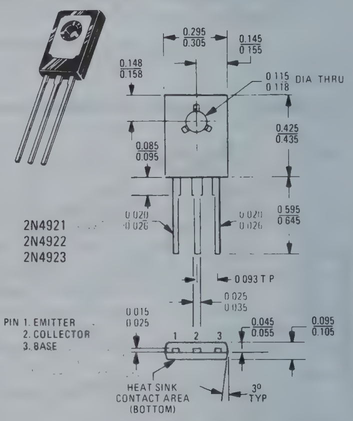
(2) Recommend use of thermal compound for lowest thermal resistance.

*Indicates JEDEC Registered Data for 2N4921 Series.

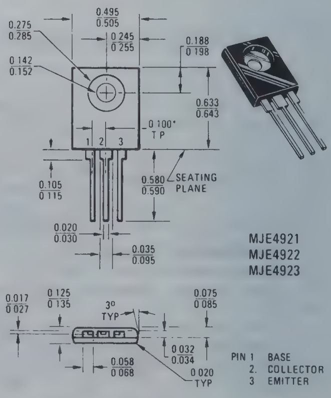
FIGURE 1 – POWER DERATING



Safe Area Curves are indicated by Figures 5 and 6. All limits are applicable and must be observed


0.295
0.305
0.145
0.155
0.148
0.158
0.115
0.118
DIA THRU
0.425
0.435
0.085
0.095
0.020
0.026
0.020
0.026
0.595
0.645
2N4921
2N4922
2N4923
0.093 T P
0.025
0.035
0.015
0.025
0.045
0.055
0.095
0.105
PIN 1. EMITTER
2. COLLECTOR
3. BASE
1
2
3
HEAT SINK
CONTACT AREA
(BOTTOM)
3°
TYP

Case 77-03
Style 1


0.495
0.505
0.275
0.285
0.245
0.255
0.188
0.198
0.142
0.152
0.633
0.643
0.100*
T P
1
2
3
0.105
0.115
0.580
0.590
SEATING
PLANE
0.020
0.030
0.035
0.095
MJE4921
MJE4922
MJE4923
0.017
0.027
0.125
0.135
3°
TYP
0.075
0.085
0.032
0.034
0.058
0.068
0.020
TYP
PIN 1 BASE
2. COLLECTOR
3 EMITTER

*Dimension is to centerline of leads

Case 199-04
Style 1

*ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (1) (I_C = 0.1 Adc, I_B = 0)	—	$V_{CEO(sus)}$			Vdc
2N4921, MJE4921			40	—	
2N4922, MJE4922			60	—	
2N4923, MJE4923			80	—	
Collector Cutoff Current	—	I_{CEO}			mAdc
(V_{CE} = 20 Vdc, I_B = 0) 2N4921, MJE4921			—	0.5	
(V_{CE} = 30 Vdc, I_B = 0) 2N4922, MJE4922			—	0.5	
(V_{CE} = 40 Vdc, I_B = 0) 2N4923, MJE4923			—	0.5	
Collector Cutoff Current	13	I_{CEX}			mAdc
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc)			—	0.1	
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 125°C)			—	0.5	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	—	I_{CBO}	—	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	—	I_{EBO}	—	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain (1)	9	h_{FE}			—
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			40	—	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)			20	100	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)			10	—	
Collector-Emitter Saturation Voltage (1) (I_C = 1.0 Adc, I_B = 0.1 Adc)	10 12 14	$V_{CE(sat)}$	—	0.6	Vdc
Base-Emitter Saturation Voltage (1) (I_C = 1.0 Adc, I_B = 0.1 Adc)	12 14	$V_{BE(sat)}$	—	1.3	Vdc
Base-Emitter On Voltage (1) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	12 14	$V_{BE(on)}$	—	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	—	f_T	3.0	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	—	C_{ob}	—	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	—	h_{fe}	25	—	—

(1) Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%.

*Indicates JEDEC Registered Data for 2N4921 Series.

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

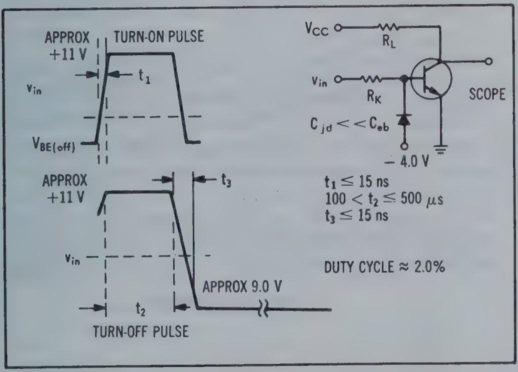

APPROX +11 V
TURN-ON PULSE
t_1
V_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
V_{in}
APPROX 9.0 V
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
$C_{jd} << C_{eb}$
SCOPE
− 4.0 V
$t_1 \leq 15$ ns
$100 < t_2 \leq 500$ μs
$t_3 \leq 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

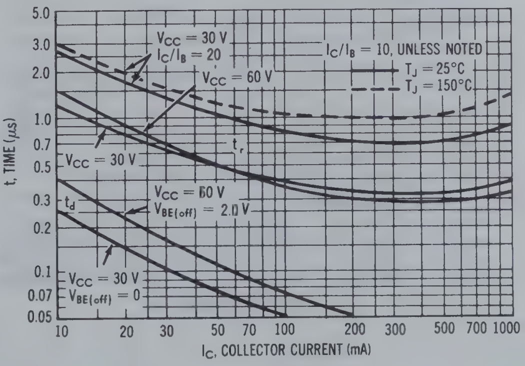
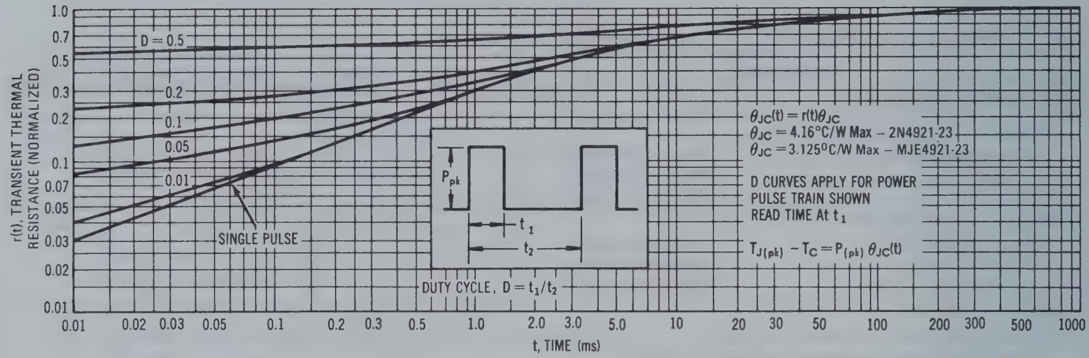


FIGURE 4 – THERMAL RESPONSE



ACTIVE – REGION SAFE OPERATING AREA

FIGURE 5 – 2N4921 thru 2N4923

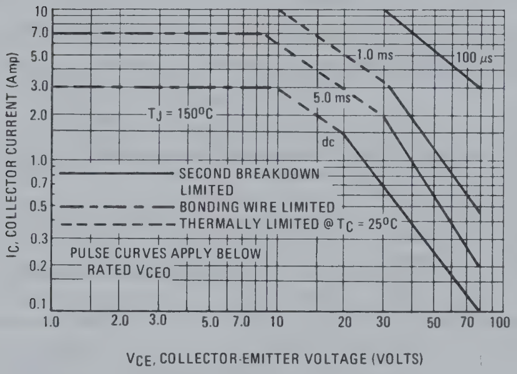
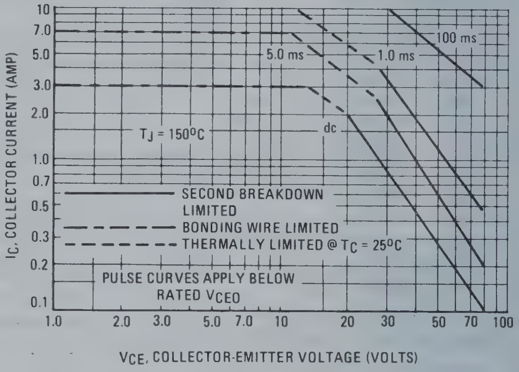


FIGURE 6 – MJE4921 thru MJE4923



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C-V_{CE} operation, i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figures 5 and 6 is based on $T_{J(pk)} = 150°C$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leqslant 150°C$. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415)

FIGURE 7 – STORAGE TIME

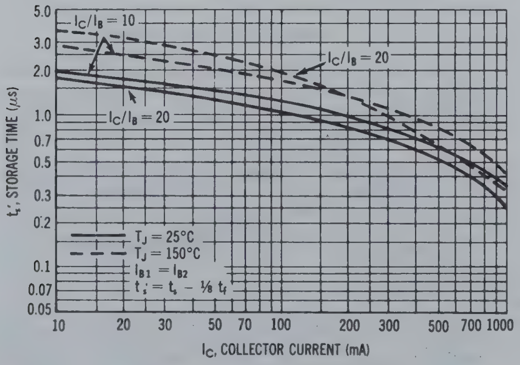


FIGURE 8 – FALL TIME

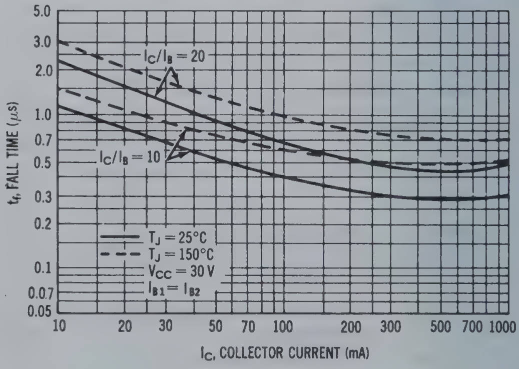


FIGURE 9 – CURRENT GAIN

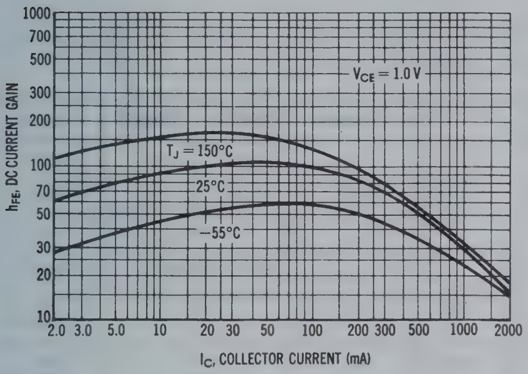


FIGURE 10 – COLLECTOR SATURATION REGION

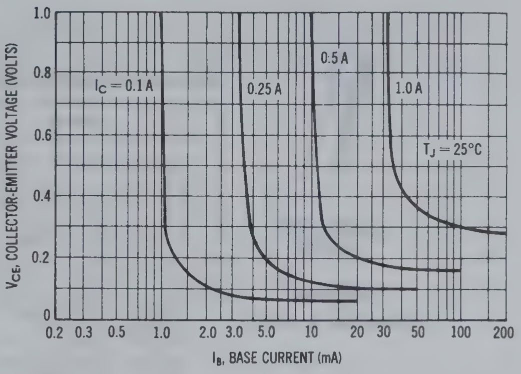


FIGURE 11 – EFFECTS OF BASE-EMITTER RESISTANCE

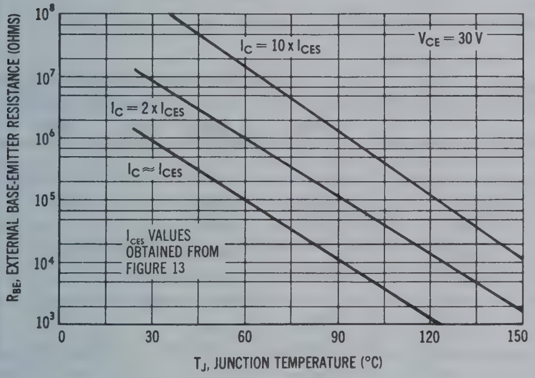


FIGURE 12 – "ON" VOLTAGE

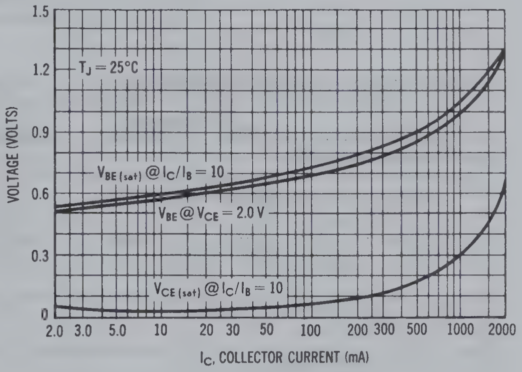


FIGURE 13 – COLLECTOR CUTOFF REGION

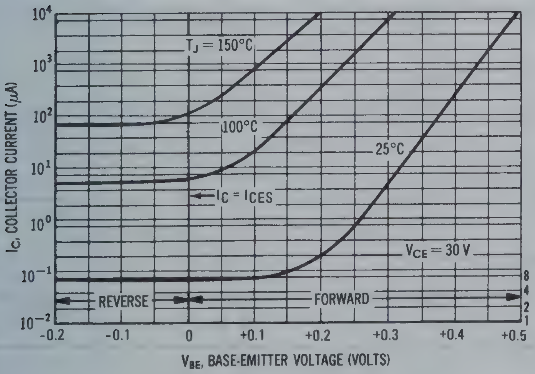
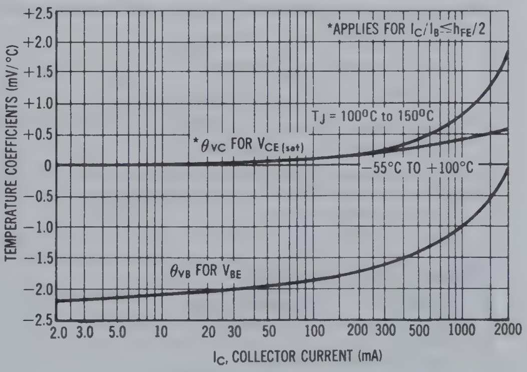
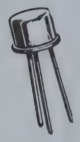


FIGURE 14 – TEMPERATURE COEFFICIENTS



2N4924 (SILICON)
2N4925

. . . NPN silicon annular transistors designed for high-voltage, high-frequency amplifier applications.



CASE 79
(TO-39)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4924	2N4925	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	Vdc
Collector-Base Voltage	V_{CB}	100	150	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	200		mAdc
Total Device Dissipation T_A = 25°C Derate above 25°C	P_D	1.0 5.71		W mW/°C
Total Device Dissipation T_C = 25°C Derate above 25°C	P_D	5.0 28.6		W mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, I_B = 0)	2N4924 2N4925	BV_{CEO}	100 150	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_C = 0)	2N4924 2N4925	BV_{CBO}	100 150	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 75 Vdc, I_E = 0)		I_{CBO}	- -	0.1 0.1	µAdc
ON CHARACTERISTICS [1]					
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc)		h_{FE}	25 35 40	- - 200	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		$V_{CE(sat)}$	- -	0.25 0.4	Vdc
Base-Emitter On Voltage (I_C = 50 mAdc, V_{CE} = 10 Vdc)		$V_{BE(on)}$	-	0.95	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain - Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	100	500	MHz
Collector-Base Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)		C_{cb}	-	10	pF
Collector-Emitter Capacitance (V_{BE} = 1.0 Vdc, I_C = 0, f = 100 kHz)		C_{eb}	-	80	pF

[1] Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

2N4926 (SILICON)
2N4927

CASE 79
(TO-39)
Collector connected to case

. . . NPN silicon annular transistors designed for high-voltage, high-frequency amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N4926	2N4927	Unit
Collector-Emitter Voltage	V_{CEO}	200	250	Vdc
Collector-Base Voltage	V_{CB}	200	250	Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current - Continuous	I_C	50		mAdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71		W mW/°C
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6		W mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage*	BV_{CEO}^*			Vdc
(I_C = 10 mAdc , I_B = 0) 2N4926		200	-	
2N4927		250	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 0.1 mAdc, I_C = 0) 2N4926		200	-	
2N4927		250	-	
Emitter-Base Breakdown Voltage (I_E = 1.0 mAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 100 Vdc, I_E = 0) 2N4926		-	0.1	
(V_{CB} = 100 Vdc, I_E = 0, T_A = 100°C)		-	10	
(V_{CB} = 150 Vdc, I_E = 0) 2N4927		-	0.1	
(V_{CB} = 150 Vdc, I_E = 0, T_A = 100°C)		-	10	
Emitter Cutoff Current (V_{BE} = 5.0 V	I_{EBO}	-	0.1	μAdc

*Pulse Width ≦ 300 μs, Duty Cycle ≦ 1.0%

ON CHARACTERISTICS				
DC Current Gain (1)	h_{FE}			-
(I_C = 3.0 mAdc, V_{CE} = 10 Vdc)		10	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		15	-	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)		20	200	
(I_C = 50 mAdc, V_{CE} = 20 Vdc)		20	-	
Collector-Emitter Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	1.0	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		-	2.0	
Base-Emitter Saturation Voltage (1)	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	1.2	
(I_C = 50 mAdc, I_B = 3.0 mAdc)			1.5	
Base-Emitter On Voltage (I_C = 30 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	1.5	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 20 MHz)	f_T	30	300	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	6.0	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	75	750	k ohm
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	0.1	1.0	$X10^{-4}$
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	250	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	5.0	50	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 5.0 MHz)	$Re(h_{ie})$	4.0	40	ohms

(1) Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%

2N4928 thru 2N4931 (SILICON)

2N4930 JAN & JTX
2N4931 JAN & JTX AVAILABLE

High-voltage PNP silicon annular transistors for use in general-purpose high-voltage applications.

CASE 79
(TO-39)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4928	2N4929	2N4930	2N4931	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	200	250	Vdc
Collector-Base Voltage	V_{CB}	100	150	200	250	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	4.0	4.0	Vdc
Collector Current — Continuous	I_C	100	500	500	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.4	1.0 5.71	1.0 5.71	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.2	5.0 28.6	5.0 28.6	5.0 28.6	Watt mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200				°C

2N4928 thru 2N4931 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1)	BV_{CEO}			Vdc
(I_C = 10 mAdc, I_B = 0) 2N4928		100	-	
2N4929		150	-	
2N4930		200	-	
2N4931		250	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_E = 0, I_C = 100 μAdc) 2N4928		100	-	
2N4929		150	-	
2N4930		200	-	
2N4931		250	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0) 2N4928		-	0.5	
(V_{CB} = 75 Vdc, I_E = 0) 2N4929		-	0.5	
(V_{CB} = 150 Vdc, I_E = 0) 2N4930, 2N4931		-	1.0	
Emitter Cutoff Current	I_{EBO}			μAdc
(V_{BE} = 3.0 Vdc, I_C = 0) 2N4928, 2N4929		-	0.5	
(V_{BE} = 3.0 Vdc, I_C = 0) 2N4930, 2N4931		-	1.0	
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) All Types		20	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) (1) 2N4928, 2N4929		25	200	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) (1) 2N4930, 2N4931		20	200	
(I_C = 50 mAdc, V_{CE} = 10 Vdc) (1) 2N4928, 2N4929		20	-	
(I_C = 30 mAdc, V_{CE} = 10 Vdc) (1) 2N4930, 2N4931		20	-	
Collector-Emitter Saturation Voltage (1)	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N4928, 2N4929		-	0.5	
2N4930, 2N4931		-	5.0	
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Gandwidth Product	f_T			MHz
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) 2N4928, 2N4929		100	1,000	
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 20 MHz) 2N4930, 2N4931		20	200	
Collector-Base Capacitance	C_{cb}			pF
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4928		-	6.0	
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4929		-	10	
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4930, 2N4931		-	20	
Emitter-Base Capacitance	C_{eb}			pF
(V_{BE} = 2.0 Vdc, I_C = 0, f = 140 kHz) 2N4928		-	40	
(V_{BE} = 1.0 Vdc, I_C = 0, f = 140 kHz) 2N4929		-	80	
(V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz) 2N4930, 2N4931		-	400	

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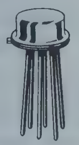
(1) Pulse Width ≤ 300 μs: Duty Cycle ≤ 2.0%

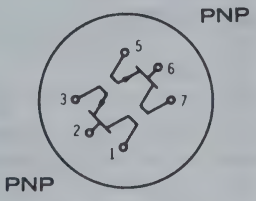
2N4937 thru 2N4942 (SILICON)

Dual PNP silicon annular transistors especially designed for low-level, differential amplifier applications.

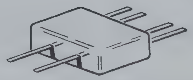


Case 654-01

2N4937
2N4938
2N4939

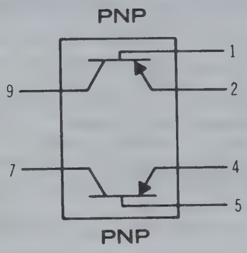


Pins 4 and 8 omitted



Case 610-02

2N4940
2N4941
2N4942



Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	50		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current -Continuous	I_C	50		mAdc
Base Current	I_B	10		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25°C$ Metal Can Derate above 25°C Flat Pack Derate above 25°C	P_D	 500 2.9 250 1.5	 600 3.4 350 2.0	 mW mW/°C mW mW/°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	50		-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0		-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	I_{CBO}	-	2.0	20	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	3.0	20	nAdc
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				-
(I_C = 100 μAdc, V_{CE} = 10 Vdc)		40	-	200	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)		50	-	250	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		50	-	250	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	400	900	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz) Emitter Guarded	C_{cb}	-	3.0	5.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz) Collector Guarded	C_{eb}	-	7.0	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{ie}	1.0	4.0	10	kΩ
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{re}	-	3.0	10	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{fe}	50	-	-	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{oe}	5.0	15	50	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 kΩ, f = 10 Hz to 15.7 kHz)	NF	-	-	4.0	dB
MATCHING CHARACTERISTICS					
DC Current Gain Ratio*	h_{FE1}/h_{FE2}*				-
(I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc) 2N4937, 2N4940		0.9	-	1.0	
2N4938, 2N4941		0.8	-	1.0	
2N4939, 2N4942		-	0.7	-	
(I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc, T_A = -55°C to +125°C) 2N4937, 2N4940		0.85	-	1.0	
2N4938, 2N4941		0.7	-	1.0	
2N4939, 2N4942		-	0.6	-	
Base Voltage Differential	$\lvert V_{BE1}-V_{BE2}\rvert$				mVdc
(I_C = 100 μA to 1.0 mAdc, V_{CE} = 10 Vdc) 2N4937, 2N4940		-	-	3.0	
2N4938, 2N4941		-	-	5.0	
2N4939, 2N4942		-	5.0	-	
Base Voltage Differential Gradient	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$				μV/°C
(I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc, T_A = -55°C to +125°C) 2N4937, 2N4940		-	-	10	
2N4938, 2N4941		-	-	20	
2N4939, 2N4942		-	20	-	

* The lowest h_{FE} reading is taken as h_{FE1} for this ratio

2N4948 (SILICON)
2N4949

CASE 22A
(TO-18 Modified)
(Lead 3 connected to case)

Silicon annular unijunction transistors designed for military and industrial use in pulse, timing, triggering, sensing, and oscillator circuits. The annular process provides low leakage current, fast switching and low peak-point currents as well as outstanding reliability and uniformity.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	360*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	1.0**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 2.4 mW/°C increase in ambient temperature. Total power dissipation (available power to Emitter and Base-Two) must be limited by external circuitry. Interbase voltage (V_{B2B1}) limited by power dissipation,

$$V_{B2B1} = \sqrt{R_{BB} \cdot P_D}.$$

** Capacitance discharge current must fall to 0.37 Amp within 3.0 ms and PRR $\leqq$ 10 PPS.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio ($V_{B2B1} = 10$ V) Note 1 — 2N4948 2N4949	η	0.55 0.74	- -	0.82 0.86	-
Interbase Resistance ($V_{B2B1} = 3.0$ V, $I_E = 0$) — 2N4948, 2N4949	R_{BB}	4.0	7.0	12.0	k ohms
Interbase Resistance Temperature Coefficient ($V_{B2B1} = 3.0$ V, $I_E = 0$, $T_A = -65°C$ to $+100°C$)	αR_{BB}	0.1	-	0.9	%/°C
Emitter Saturation Voltage ($V_{B2B1} = 10$ V, $I_E = 50$ mA) Note 2	$V_{EB1(sat)}$	-	2.5	3.0	Volts
Modulated Interbase Current ($V_{B2B1} = 10$ V, $I_E = 50$ mA)	$I_{B2(mod)}$	12	15	-	mA
Emitter Reverse Current ($V_{B2E} = 30$ V, $I_{B1} = 0$) ($V_{B2E} = 30$ V, $I_{B1} = 0$, $T_A = 125°C$)	I_{EB2O}	- -	5.0 -	10 1.0	nA µA
Peak Point Emitter Current ($V_{B2B1} = 25$ V) — 2N4948 2N4949	I_P	- -	0.6 0.6	2.0 1.0	µA
Valley Point Current ($V_{B2B1} = 20$ V, $R_{B2} = 100$ ohms) Note 2 — 2N4948, 2N4949	I_V	2.0	4.0	- -	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3) — 2N4949 2N4948	V_{OB1}	3.0 6.0	5.0 8.0	- -	Volts
Maximum Oscillation Frequency (Figure 4)	$f_{(max)}$	-	1.25	-	MHz

NOTES

1. Intrinsic standoff ratio.
η, is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop
(≈ 0.5 V @ 10 µA)

2. Use pulse techniques: PW ≈ 300 µs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

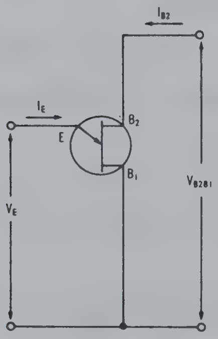


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

(Exaggerated to Show Details)

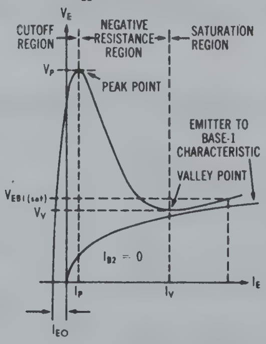


FIGURE 3 — V_{OB1} TEST CIRCUIT
(Typical Relaxation Oscillator)

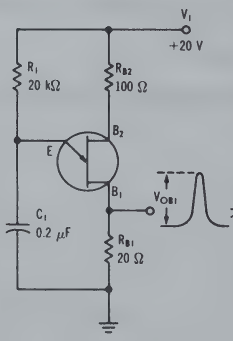
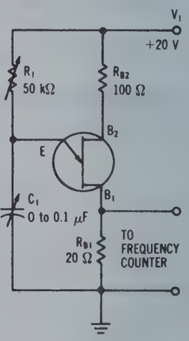


FIGURE 4 — F(max) MAXIMUM FREQUENCY TEST CIRCUIT



2N4957 (SILICON)
2N4958
2N4959

PNP silicon annular small-signal RF transistor designed for high-gain, low-noise amplifier, oscillator, and mixer applications.

CASE 20
(TO-72)

Active elements isolated from case

MAXIMUM RATINGS

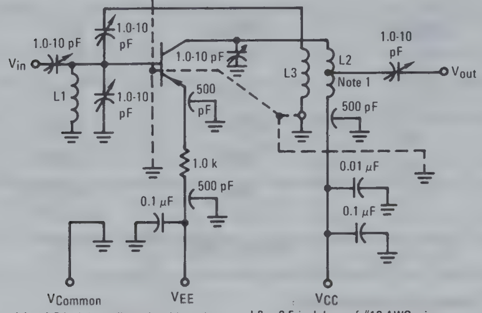
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current — Continuous	I_C	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	200 1.14	mWatt mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)		BV_{CEO}	30	—	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100$ μAdc, $I_E = 0$)		BV_{CBO}	30	—	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100$ μAdc, $I_C = 0$)		BV_{EBO}	3.0	—	—	Vdc
Collector Cutoff Current ($V_{CB} = 20$ Vdc, $I_E = 0$) ($V_{CB} = 20$ Vdc, 0, $T_A = 150°C$)		I_{CBO}	— —	— —	0.1 100	μAdc
ON CHARACTERISTICS						
DC Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc)		h_{FE}	20	40	—	—
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product ($I_E = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz)	2N4957 2N4958, 2N4959	f_T	1200 1000	1600 1500	— —	MHz
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)		C_{cb}	—	0.4	0.8	pF
Collector-Base Time Constant ($I_E = 2.0$ mAdc, $V_{CB} = 10$ Vdc, f = 63.6 MHz)		$r_b'C_C$	—	—	8.0	ps
Noise Figure ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 450 MHz) Fig. 1	2N4957 2N4958 2N4959	NF	— — —	2.6 2.9 3.2	3.0 3.3 3.8	dB
($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, $R_G = 50$ ohms, f = 1.0 GHz)	2N4957		—	5.0	—	
FUNCTIONAL TESTS						
Common-Emitter Amplifier Power Gain ($V_{CE} = 10$ Vdc, $I_C = 2.0$ mAdc, f = 450 MHz)	2N4957 2N4958 2N4959	G_{pe}	17 16 15	— — —	— — —	dB
($V_{CE} = 10$ Vdc, $I_C = 2.0$ mAdc, $R_G = 50$ ohms, f = 1.0 GHz)	2N4957		—	13	—	

RF PERFORMANCE DATA

FIGURE 1 – NOISE FIGURE AND POWER GAIN TEST CIRCUIT


1.0-10 pF
1.0-10 pF
1.0-10 pF
1.0-10 pF
1.0-10 pF
1.0-10 pF
Vin
Vout
L1
L2
L3
Note 1
500 pF
500 pF
500 pF
1.0 k
0.1 μF
0.01 μF
0.1 μF
VCommon
VEE
VCC

L1 – 1.0 inch long silver plated brass bar stock 0.25 inches in diameter.
L2 – 1.625 inch long, same as L1.
L3 – 0.5 inch loop of #16 AWG wire 0.375 inches from and parallel to L2.
Note 1: Tap is 0.25 inches from hot end.

FIGURE 2 – UNILATERALIZED POWER GAIN versus FREQUENCY

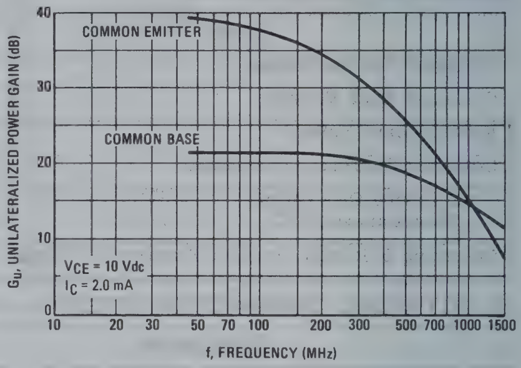


FIGURE 3 – NOISE FIGURE versus FREQUENCY

(R_S & I_C OPTIMIZED FOR BROAD BAND PERFORMANCE)

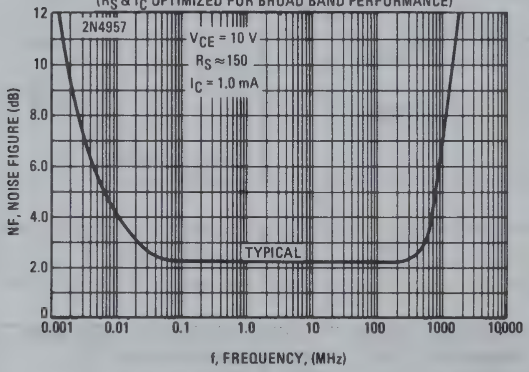


FIGURE 4 – NOISE FIGURE AND POWER GAIN versus COLLECTOR CURRENT

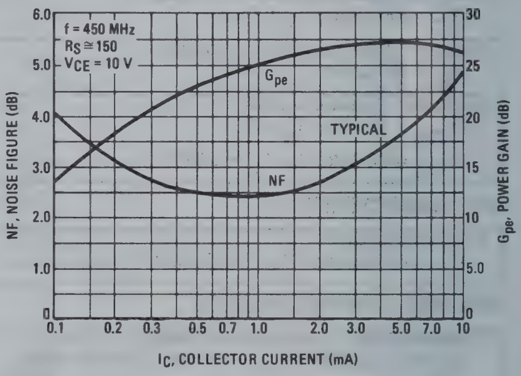


FIGURE 5 – CONTOURS OF NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT

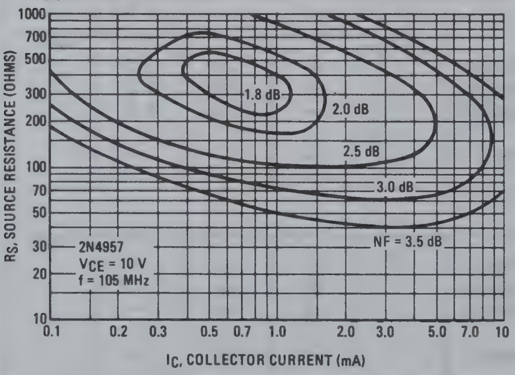
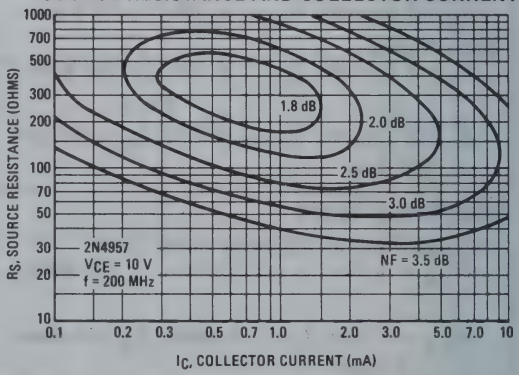


FIGURE 6 – CONTOURS OF NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT



COMMON EMITTER CIRCUIT DESIGN DATA

(V_{CE} = 10 Vdc, I_C = 2.0 mA)

FIGURE 7 – TRANSDUCER GAIN versus FREQUENCY

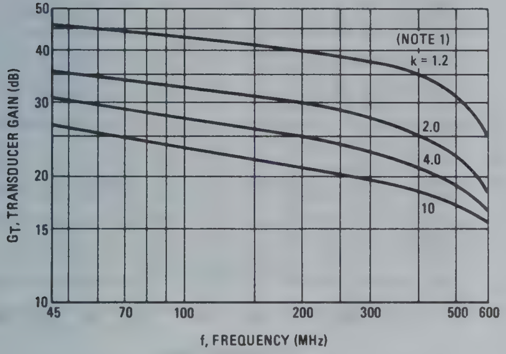


FIGURE 8 – LINVILL STABILITY FACTOR versus FREQUENCY

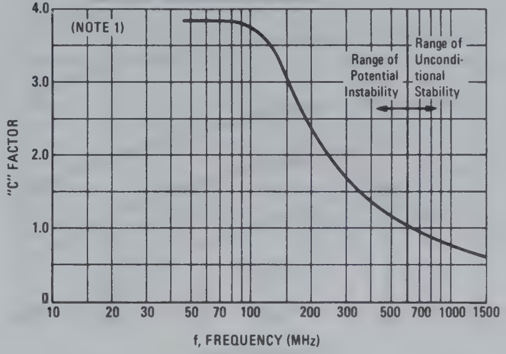


FIGURE 9 – LOAD ADMITTANCE versus FREQUENCY (REAL)

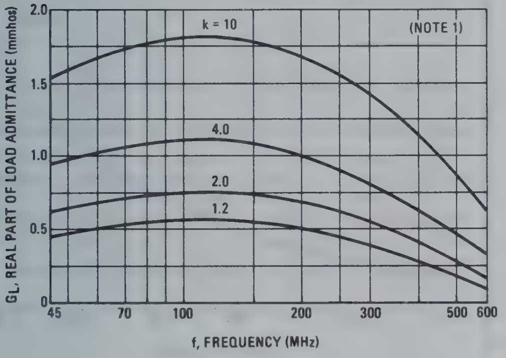


FIGURE 10 – LOAD ADMITTANCE versus FREQUENCY (IMAGINARY)

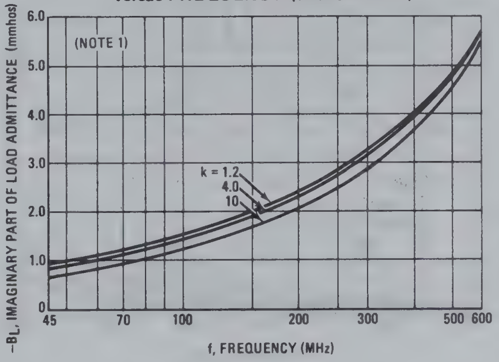


FIGURE 11 – SOURCE ADMITTANCE versus FREQUENCY (REAL)

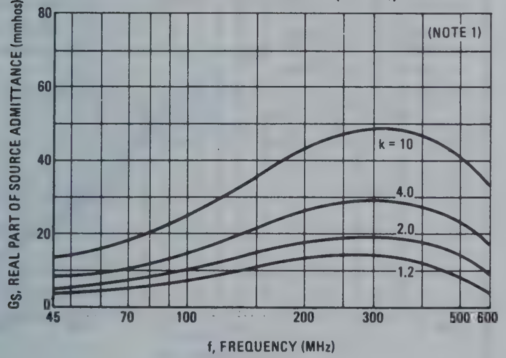
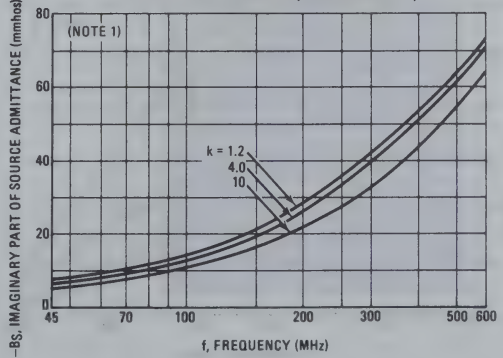


FIGURE 12 – SOURCE ADMITTANCE versus FREQUENCY (IMAGINARY)



NOTE 1

Figures 7 through 18 are included to assist the circuit designer in determining the stability of his particular circuit. Two stability criteria are given in these figures.

The Linvill "C" factor* is a measure of transistor stability when the input and output are terminated in the worst-case (open circuit) condition. When "C" is less than 1.0, the circuit is unconditionally stable. When "C" is greater than 1.0, the circuit is potentially unstable.

The Stern "K" factor† has been defined to determine the stability of a practical amplifier terminated in finite load and source admittances. If "K" is greater than 1.0, the circuit will be stable. If less than 1.0, the circuit will be unstable. For further details, see Application Note AN-215.

---

* "Transistors and Active Circuits," Linvill and Gibbons, McGraw-Hill, 1961.

† "Stability and Power Gain of Tuned Transistor Amplifiers," Arthur P. Stern, Proc. I.R.E., March 1967.

COMMON BASE CIRCUIT DESIGN DATA

(V_{CB} = 10 Vdc, I_C = 2.0 mA)

FIGURE 13 – TRANSDUCER GAIN versus FREQUENCY

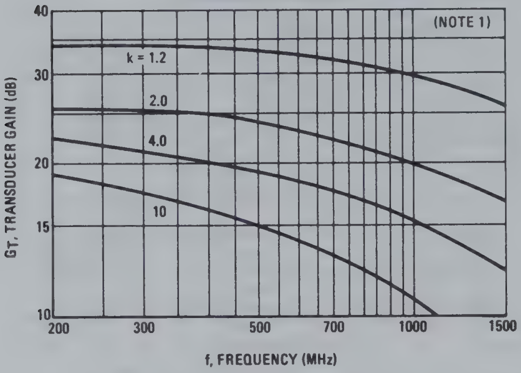


FIGURE 14 – LINVILL STABILITY FACTOR versus FREQUENCY

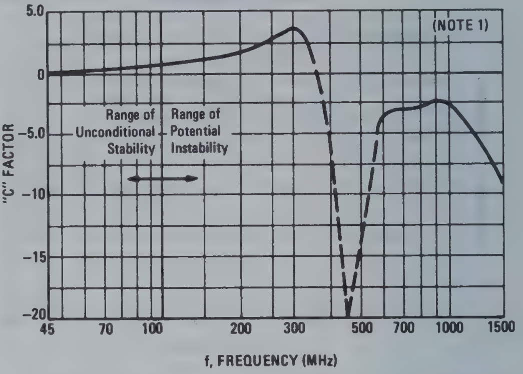


FIGURE 15 – LOAD ADMITTANCE versus FREQUENCY (REAL)

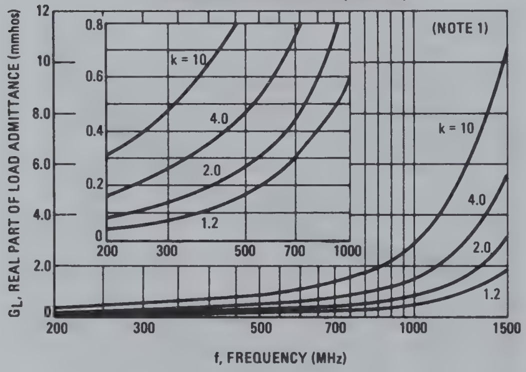


FIGURE 16 – LOAD ADMITTANCE versus FREQUENCY (IMAGINARY)

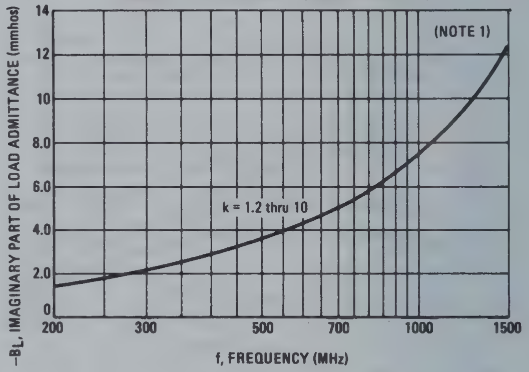


FIGURE 17 – SOURCE ADMITTANCE versus FREQUENCY (REAL)

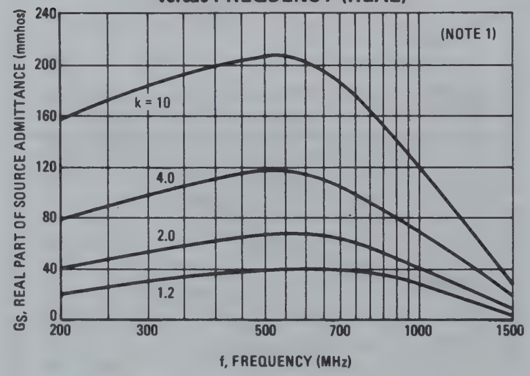


FIGURE 18 – SOURCE ADMITTANCE versus FREQUENCY (IMAGINARY)

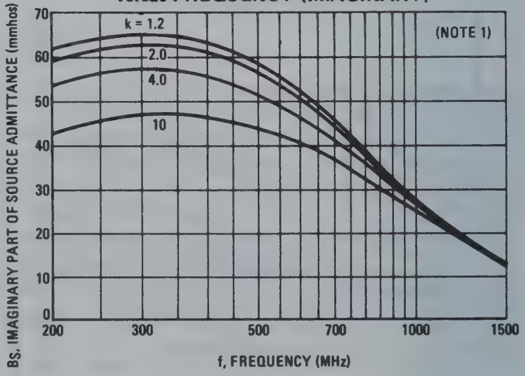


FIGURE 19 – SMALL-SIGNAL CURRENT GAIN versus FREQUENCY

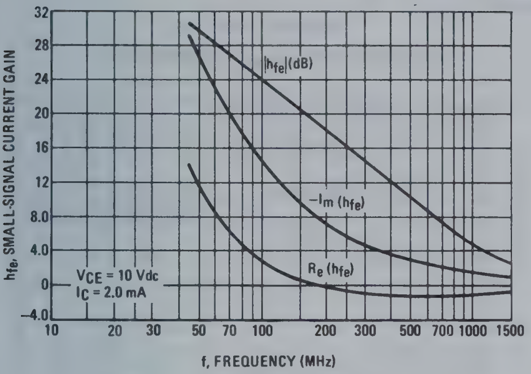


FIGURE 20 – POLAR h_{fe}

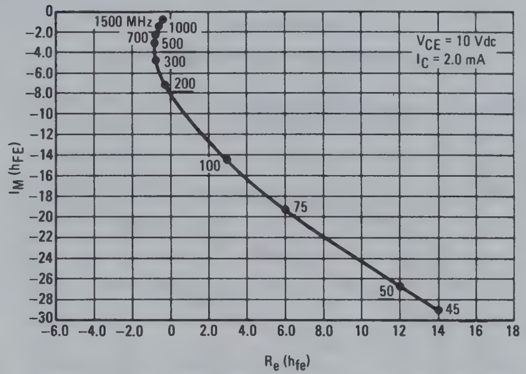


FIGURE 21 – f_T versus COLLECTOR CURRENT

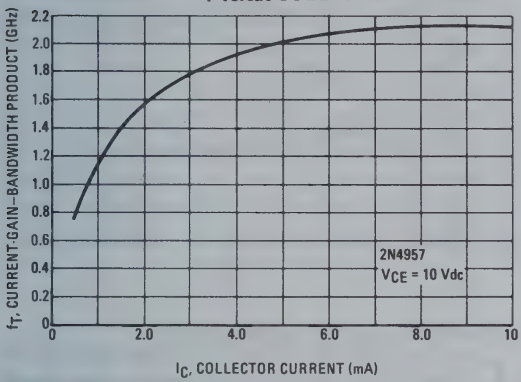


FIGURE 22 – DC CURRENT GAIN

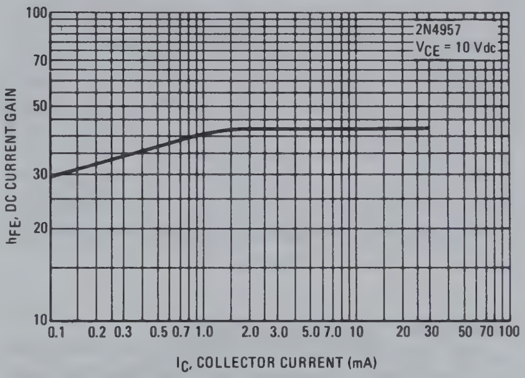


FIGURE 23 – CAPACITANCE

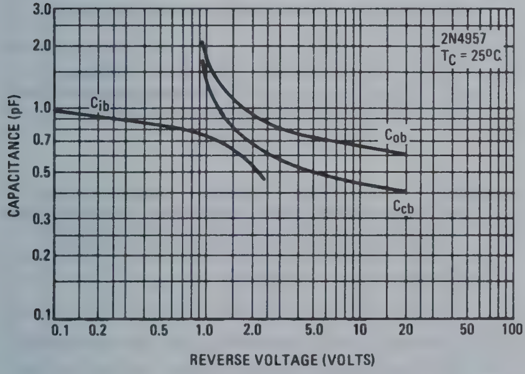
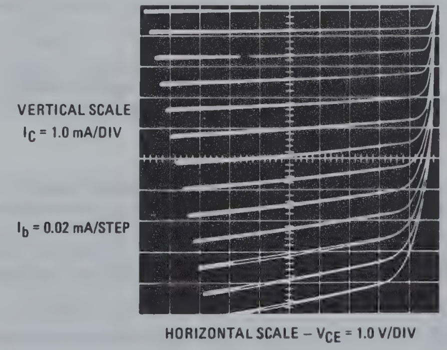
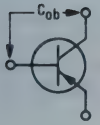
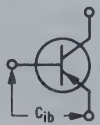


FIGURE 24 – COLLECTOR CHARACTERISTICS

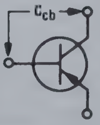




Apply reverse bias between collector and base and measure capacitance between these terminals. Emitter is open.



Apply reverse bias between emitter and base and measure capacitance between these terminals. Collector is open.



Apply reverse bias between collector and base and measure capacitance between these terminals. Emitter is guarded.

Y PARAMETERS versus CURRENT

f = 450 MHz

COMMON BASE

V_{CB} = 10 Vdc ——— V_{CB} = 15 Vdc – – –

COMMON EMITTER

V_{CE} = 10 Vdc ——— V_{CE} = 15 Vdc – – –

FIGURE 25 – INPUT ADMITTANCE

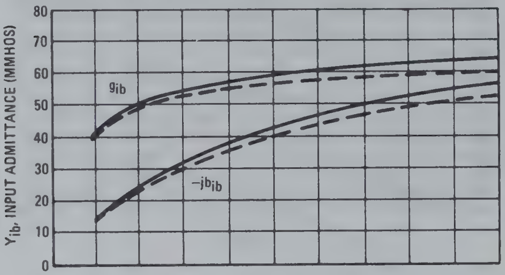


FIGURE 26 – INPUT ADMITTANCE

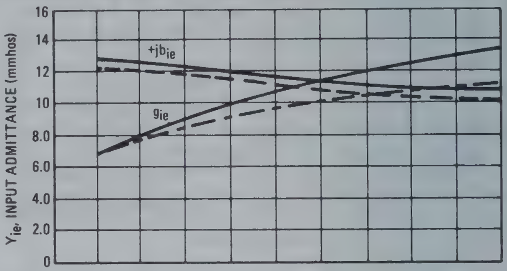


FIGURE 27 – FORWARD TRANSFER ADMITTANCE

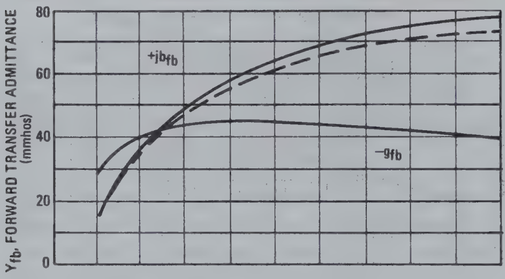


FIGURE 28 – FORWARD TRANSFER ADMITTANCE

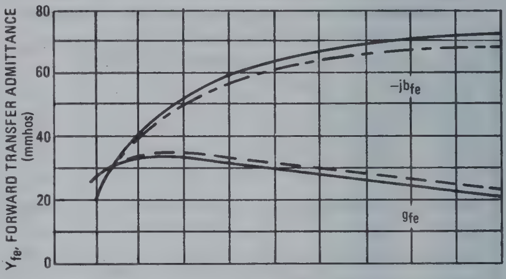


FIGURE 29 – OUTPUT ADMITTANCE

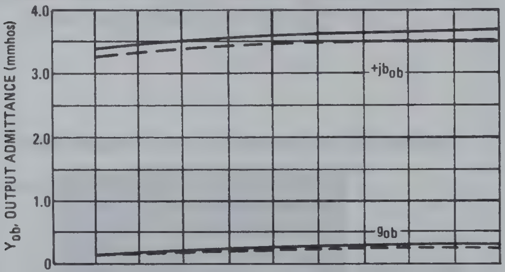


FIGURE 30 – OUTPUT ADMITTANCE

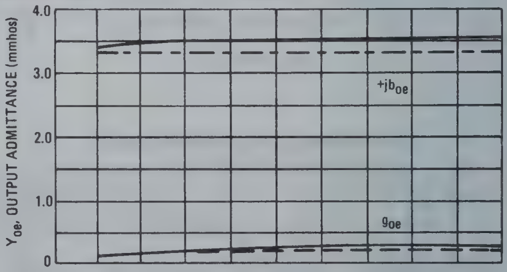


FIGURE 31 – REVERSE TRANSFER ADMITTANCE

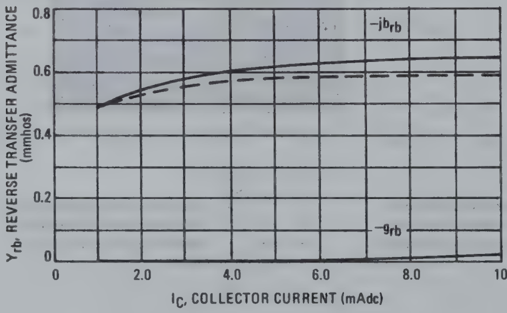
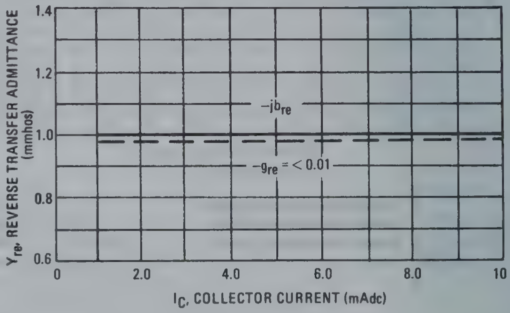


FIGURE 32 – REVERSE TRANSFER ADMITTANCE



COMMON BASE Y PARAMETER VARIATIONS

(V_{CB} = 10 Vdc, I_C = 2.0 mAdc)

Y PARAMETERS versus FREQUENCY

FIGURE 33 – y_{ib} INPUT ADMITTANCE

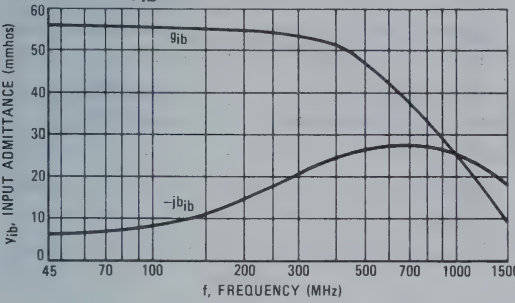


FIGURE 35 – y_{fb} FORWARD TRANSFER ADMITTANCE

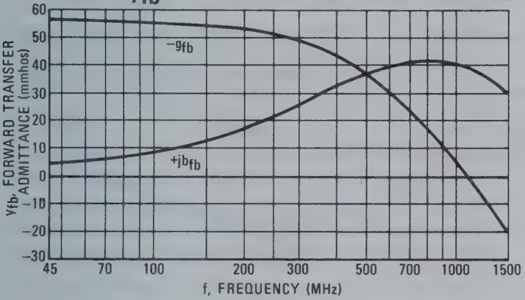


FIGURE 37 – y_{ob} OUTPUT ADMITTANCE

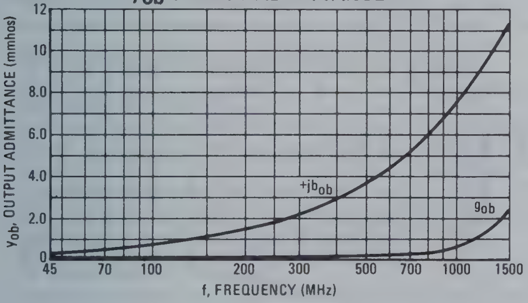
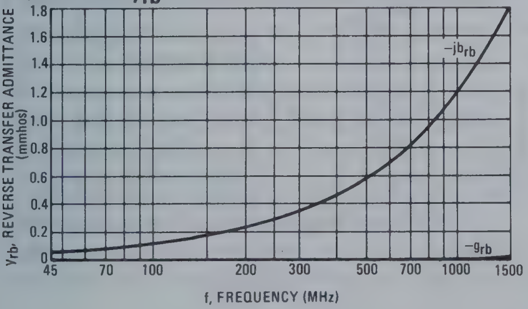


FIGURE 39 – y_{rb} REVERSE TRANSFER ADMITTANCE



POLAR Y PARAMETERS versus FREQUENCY

FIGURE 34 – y_{ib} INPUT ADMITTANCE

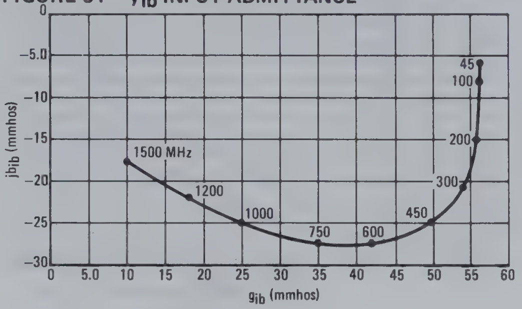


FIGURE 36 – y_{fb} FORWARD TRANSFER ADMITTANCE

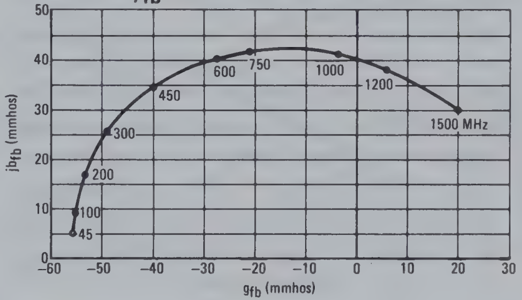


FIGURE 38 – y_{ob} OUTPUT ADMITTANCE

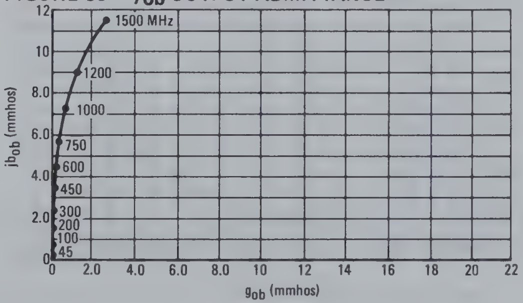
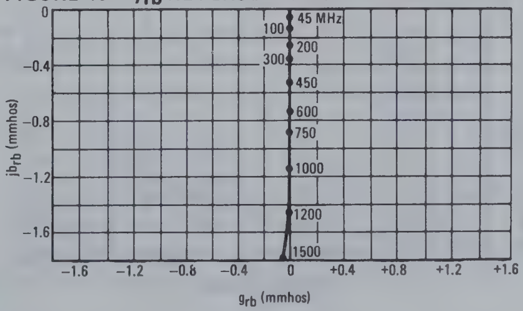


FIGURE 40 – y_{rb} REVERSE TRANSFER ADMITTANCE



COMMON EMITTER Y PARAMETER VARIATIONS

(V_{CE} = 10 Vdc, I_C = 2.0 mA)

Y PARAMETERS versus FREQUENCY

FIGURE 41 – y_{ie} INPUT ADMITTANCE

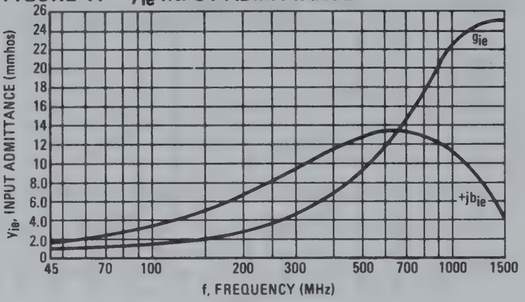


FIGURE 43 – y_{fe} FORWARD TRANSFER ADMITTANCE

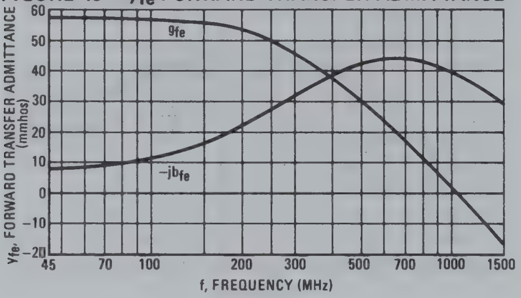


FIGURE 45 – y_{oe} OUTPUT ADMITTANCE

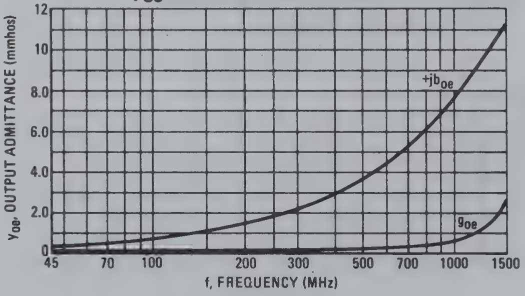
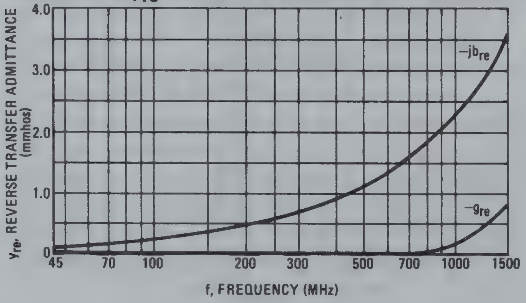


FIGURE 47 – y_{re} REVERSE TRANSFER ADMITTANCE



POLAR Y PARAMETERS versus FREQUENCY

FIGURE 42 – y_{ie} INPUT ADMITTANCE

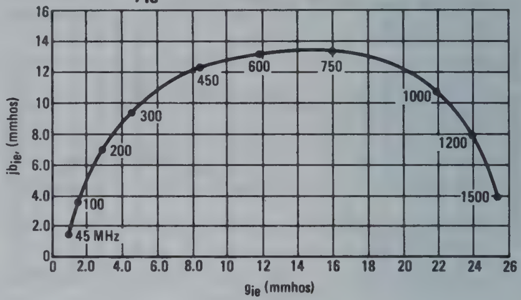


FIGURE 44 – y_{fe} FORWARD TRANSFER ADMITTANCE

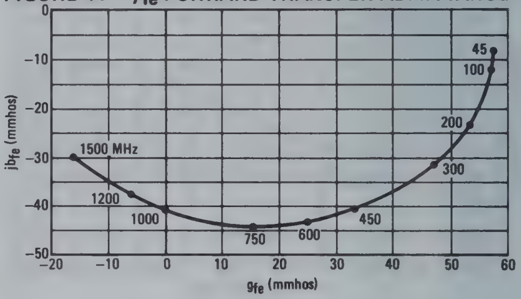


FIGURE 46 – y_{oe} OUTPUT ADMITTANCE

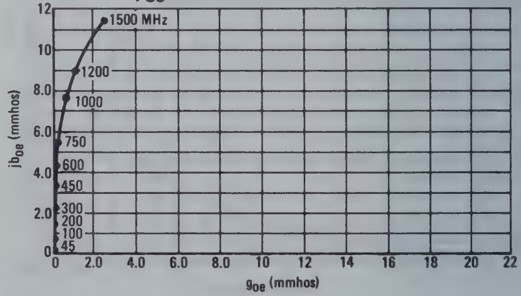
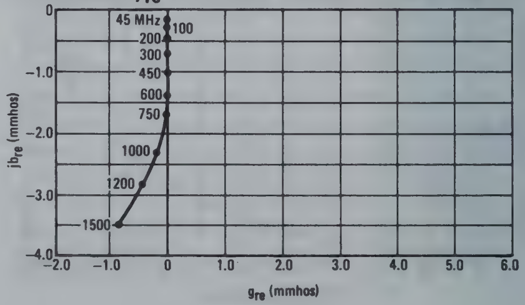


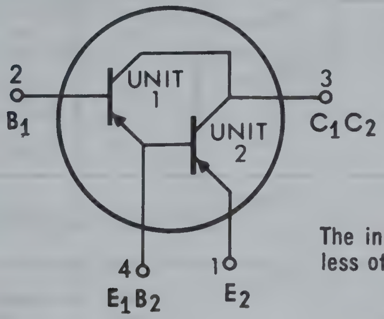
FIGURE 48 – y_{re} REVERSE TRANSFER ADMITTANCE



2N4974 (SILICON)
2N4975

CASE 34A
(TO-12)

PNP silicon annular darlington amplifiers contain two PNP silicon annular transistors connected as a darlington amplifier.



The input unit is identified as Unit 1 regardless of terminal numbering.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Numerical subscripts refer to unit number

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (Base 1 and Base 2 open)	V_{CE2}	30	Vdc
Collector-Base Voltage	V_{CB1}	40	Vdc
Emitter-Base Voltage	V_{E2B1}	10	Vdc
Collector Current — Continuous	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 4.57	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.5 14.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Unit
Thermal Resistance, Junction to Case Output Device Driver Device	θ_{JC}	 60 85	°C/W
Thermal Resistance, Junction to Junction	θ_{JJ}	30	°C/W

2N4974, 2N4975 (continued)

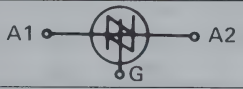
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Numerical subscripts refer to unit number, lead 4 open unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage [1] (I_C = 10 mAdc, E_2B_1 termination open)	BV_{CE2}	30	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc)	BV_{CB1O}	40	50	-	Vdc
Emitter-Base Breakdown Voltage (I_{B1} = 10 µAdc)	BV_{E2B1O}	10	12.5	-	Vdc
Collector Cutoff Current (V_{CB1} = 30 Vdc)	I_{CB1O}	-	0.5	10	nAdc
Emitter Cutoff Current (V_{E2B1} = 5.0 Vdc)	I_{E2B1O}	-	0.15	10	nAdc
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				-
(I_C = 1.0 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		5,000	9,000	-	
2N4975		1,000	4,000	-	
(I_C = 1.0 µAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C) 2N4974		-	2,000	-	
2N4975		-	1,000	-	
(I_C = 10 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		10,000	15,000	-	
2N4975		5,000	9,000		
(I_C = 10 µAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C) 2N4974		-	3,500	-	
2N4975		-	2,000	-	
(I_C = 100 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		20,000	30,000	-	
2N4975		10,000	20,000	-	
(I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc) 2N4974		25,000	50,000	-	
2N4975		15,000	30,000		
(I_C = 10 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		30,000	60,000	150,000	
2N4975		15,000	30,000	75,000	
(I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C) [1] 2N4974		-	15,000	-	
2N4975		-	10,000	-	
(I_C = 100 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		25,000	50,000	-	
2N4975		15,000	30,000	-	
(I_C = 500 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		15,000	25,000	-	
2N4975		5,000	10,000	-	
(I_C = 1.0 Adc, V_{CE2} = 5.0 Vdc)* 2N4974		2,000	4,000	-	
2N4975		1,000	2,000	-	
Collector-Emitter Saturation Voltage [1] (I_C = 500 mAdc, I_{B1} = 1.0 mAdc)	$V_{CE2(sat)}$	-	1.4	2.0	Vdc
Base-Emitter Voltage [1] (I_C = 500 mAdc, I_{B1} = 1.0 mAdc)	V_{B1E2}	-	2.0	2.7	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE2} = 5.0 Vdc, f = 100 MHz)	f_T	175	275	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 140 kHz)	C_{ob1}	-	4.0	8.0	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}				-
2N4974		25,000	-	-	
2N4975		15,000	-	-	
Noise Figure (I_C = 1.0 mAdc, V_{CB1} = 10 Vdc, R_S = 10 k ohms, BW = 15.7 kHz)	NF	-	3.0	6.0	dB

[1] Pulse Test: Pulse width ≦ 300 µs, duty cycle ≦ 2%

2N4993 (SILICON)



SILICON BIDIRECTIONAL SWITCH

. . . designed for full-wave triggering in Triac phase control circuits, half-wave SCR triggering applications and as voltage level detectors.

- Low Switching Voltage – 8.0 Volts Typical
- Uniform Characteristics in Each Direction
- Low On-State Voltage – 1.7 Volts Maximum
- Low Off-State Current – 1.0 μA Maximum
- Low Temperature Coefficient – 0.02 %/°C Typical

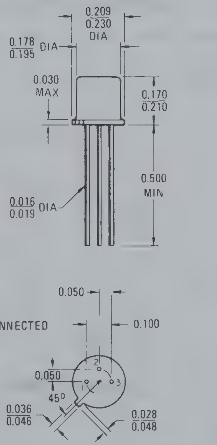
SILICON BIDIRECTIONAL SWITCH

6.0–10 VOLTS
350 mW

*MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Dissipation	P_D	350	mW
DC Forward Anode Current	I_F	200	mA
DC Gate Current (off-state only)	$I_G(off)$	5.0	mA
Repetitive Peak Forward Current (1.0% Duty Cycle, 10 μs Pulse Width)	$I_{FM}(rep)$	1.0	Amp
Non-Repetitive Forward Current 10 μs Pulse Width	$I_{FM}(nonrep)$	5.0	Amp
Operating Junction Temperature Range	T_J	-55 to +150	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data



STYLE 9
PIN 1. ANODE 2
2. ANODE 1
3. GATE (CONNECTED TO CASE)

To convert inches to millimeters multiply by 25.4
All JEDEC dimensions and notes apply

Gate Connected to Case
CASE 22 (9)
(TO-18)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
*Switching Voltage	V_S	6.0	8.0	10	Vdc
*Switching Current	I_S	–	175	500	µAdc
*Switching Voltage Differential	$\|V_{S1}-V_{S2}\|$	–	0.3	0.5	Vdc
Holding Current	I_H	–	0.7	1.5	mAdc
*Off-State Blocking Current	I_B				µAdc
(V_F = 5.0 Vdc, T_A = 25°C)		–	0.08	1.0	
(V_F = 5.0 Vdc, T_A = 100°C)		–	6.0	10	
*Forward On-State Voltage (I_F = 200 mAdc)	V_F	–	1.4	1.7	Vdc
Peak Output Voltage (C_c = 0.1 µF, R_L = 20 ohms, (Figure 7)	V_o	3.5	4.8	–	Vdc
Turn-On Time (Figure 8)	t_{on}	–	1.0	–	µs
Turn-Off Time (Figure 9)	t_{off}	–	30	–	µs
Temperature Coefficient of Switching Voltage	T_C	–	+0.02	–	%/°C
*Switching Current Differential	$\|I_{S2}-I_{S1}\|$	–	–	100	µAdc

*Indicates JEDEC Registered Data

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 1 – SWITCHING VOLTAGE versus TEMPERATURE

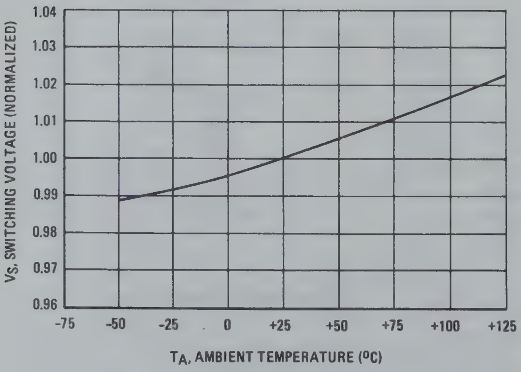


FIGURE 2 – SWITCHING CURRENT versus TEMPERATURE

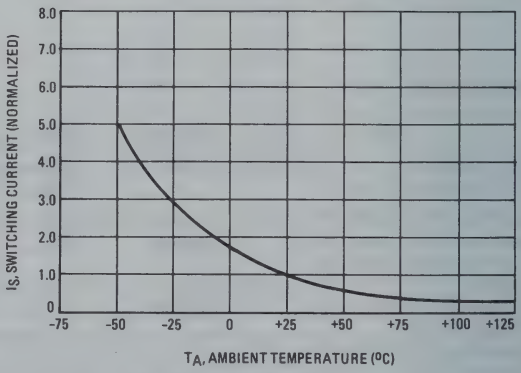


FIGURE 3 – HOLDING CURRENT versus TEMPERATURE

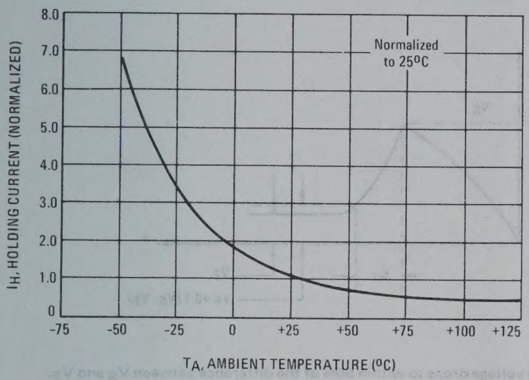


FIGURE 4 – OFF-STATE BLOCKING CURRENT versus TEMPERATURE

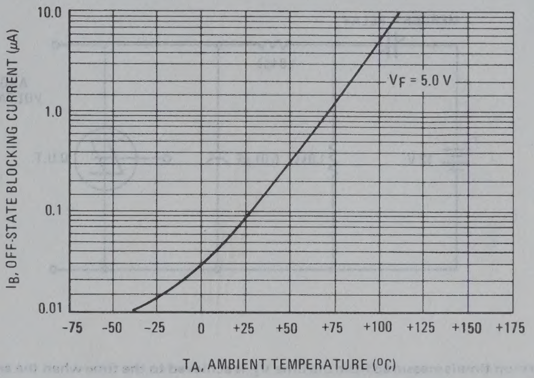


FIGURE 5 – ON-STATE VOLTAGE versus FORWARD CURRENT

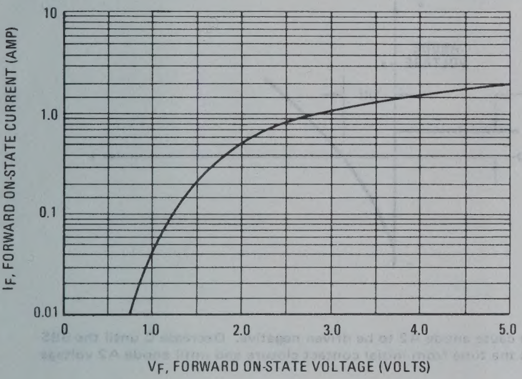


FIGURE 6 – PEAK OUTPUT VOLTAGE (FUNCTION OF R_L AND C_c)

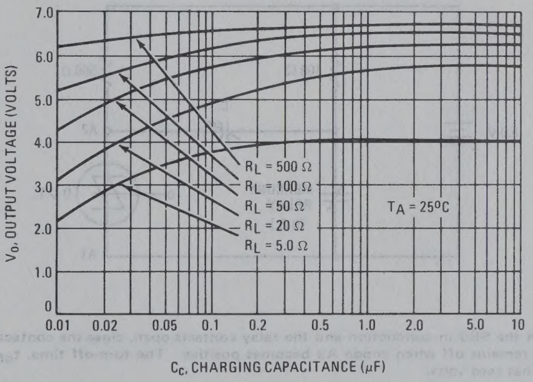


FIGURE 7 – PEAK OUTPUT VOLTAGE TEST CIRCUIT

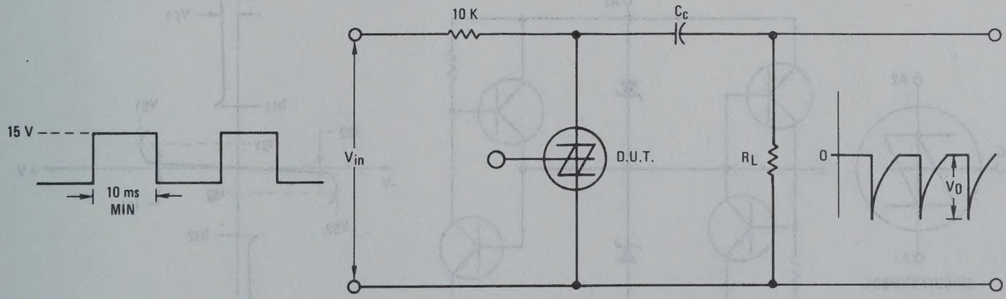
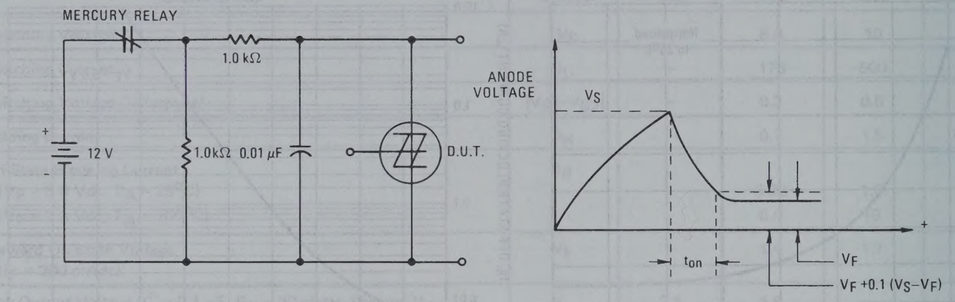
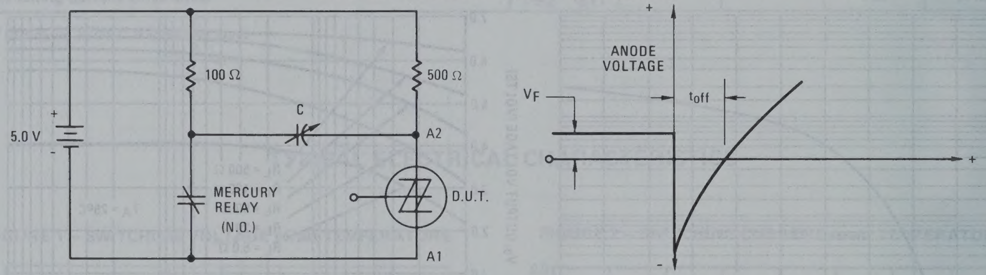

15 V
10 ms MIN
10 K
C_c
V_{in}
D.U.T.
R_L
0
V_O

FIGURE 8 – TURN-ON TIME TEST CIRCUIT


MERCURY RELAY
1.0 kΩ
+
12 V
1.0kΩ
0.01 μF
D.U.T.
ANODE VOLTAGE
VS
ton
VF
VF +0.1 (VS–VF)
+

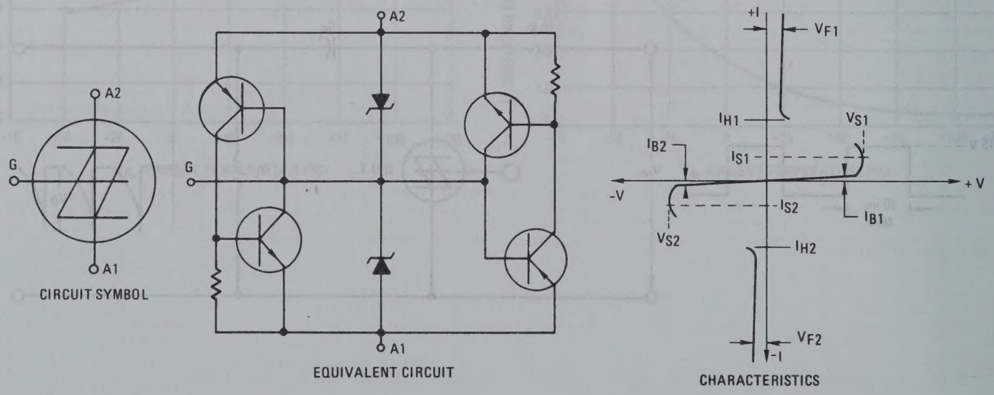
Turn-on time is measured from the time V_S is achieved to the time when the anode voltage drops to within 90% of the difference between V_S and V_F.

FIGURE 9 – TURN-OFF TIME TEST CIRCUIT


100 Ω
500 Ω
+
5.0 V
-
C
A2
MERCURY RELAY (N.O.)
D.U.T.
A1
+
ANODE VOLTAGE
VF
toff
+
-

With the SBS in conduction and the relay contacts open, close the contacts to cause anode A2 to be driven negative. Decrease C until the SBS just remains off when anode A2 becomes positive. The turn-off time, t_{off}, is the time from initial contact closure and until anode A2 voltage reaches zero volts.

FIGURE 10 – DEVICE EQUIVALENT CIRCUIT, CHARACTERISTICS AND SYMBOLS


A2
G
A1
A2
G
A1
+I
VF1
IH1
VS1
IB2
IS1
-V
+V
IS2
IB1
VS2
IH2
VF2
-I

CIRCUIT SYMBOL

EQUIVALENT CIRCUIT

CHARACTERISTICS

ENGINE
DAYTON, OHIO
JAN 28 1974